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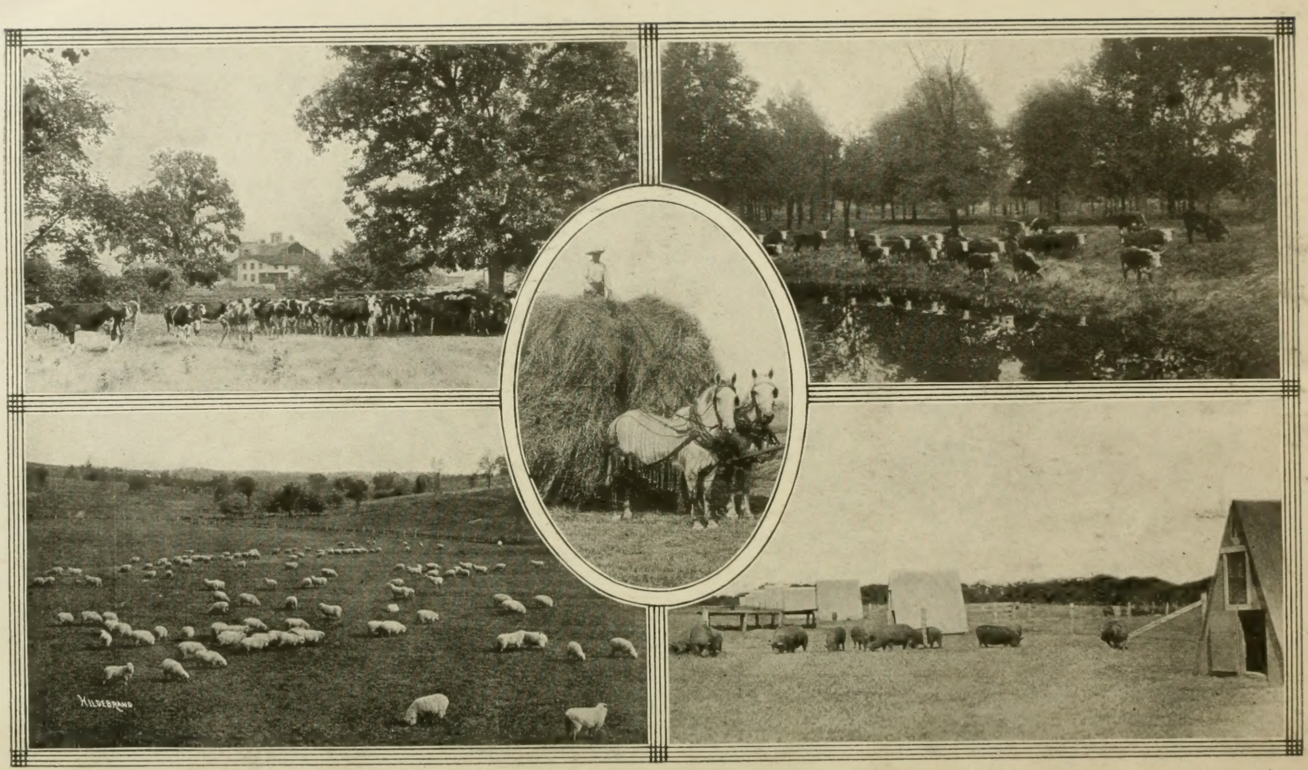

LIVE STOCK FARMING PROMOTES PERMANENT AND PROGRESSIVE AGRICULTURE

FEEDS AND FEEDING ABRIDGED

THE ESSENTIALS OF THE FEEDING, CARE, AND MANAGEMENT OF FARM ANIMALS, INCLUDING POULTRY

Adapted and Condensed from FEEDS AND FEEDING
(Eighteenth Edition)

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PREFACE

"Feeds and Feeding," first published in March, 1898, was received with widespread favor by practical stockmen and by the teachers and students of animal husbandry in this country. Since this date seventeen editions have come from the press, and the book has been twice entirely rewritten to include new and important data. Many stockmen rely upon "Feeds and Feeding" as the guide in their feeding operations, and it is the standard text on stock feeding in practically all the agricultural colleges in this country. As "Feeds and Feeding" covers the feeding and care of each class of live stock in a comprehensive manner, it is of necessity a large book, containing much detailed information.

With the rapid development of special agricultural courses in secondary schools and of short courses in the agricultural colleges, a demand arose for a simplified and condensed edition of the work. In response to this demand "Feeds and Feeding, Abridged," was prepared in 1917 by the undersigned, with the editorial aid of Professor W. A. Henry. The book was based chiefly upon "Feeds and Feeding" but the subject matter was so condensed and simplified as to adapt it for use in brief courses in stock feeding. Omitting topics of purely scientific interest, the most essential facts concerning animal nutrition and the practical feeding, care, and management of farm animals were presented in the simplest possible terms. The immediate and widespread demand for the book has been a pleasant surprise, five printings having already been required. This edition has been carefully revised to meet the changed conditions since the World War and to include important new information on the feeding of live stock.

In most brief books on stock feeding the care and management of stock receive scant attention, but in "Feeds and Feeding, Abridged" these subjects, which are of the utmost practical importance, are fully treated. To aid the teacher and the student, each chapter closes with questions covering the subject matter, and 116 engravings illustrate some of the most important points. Since the subject of poultry feeding is commonly included in live stock feeding in secondary schools, chapters have been added on the feeding and care of poultry. Altho thus covering a larger field, "Feeds and Feeding, Abridged" contains but half as much text matter as "Feeds and Feeding."

Part I presents the most important general principles governing the rational feeding and care of farm animals. The various feeding standards are briefly discussed, including the new Morrison (Modified Wolff-Lehmann) Standards, which are based upon the recent findings of the scientists in this and other countries. A chapter on "Economy in Feeding Live Stock" points out some of the economic principles which must be considered in the feeding and care of live stock to realize the largest profits.

Part II discusses all the important feeding stuffs used in this country, rather than merely the feeds available in any particular district. This permits the teacher to give the most attention to the feeds of local importance, perhaps omitting others entirely. Finally, the chapter on "Manurial Value of Feeding Stuffs," points out the vital relation of animal husbandry to the economical maintenance of soil fertility.

Part III takes up the practical feeding, care, and management of each class of live stock and summarizes the special value of the important feeds for each class of animals. Most of the tables giving summaries of the important feeding trials at the Experiment Stations, contained in the corresponding part of "Feeds and Feeding," are omitted in the abridged edition. Instead, the authors have presented in simple terms their conclusions on the value of the different feeding stuffs and of the various methods of feeding and caring for stock.

The Appendix Tables, condensed from the much more extensive Appendix Tables of "Feeds and Feeding," show the composition and the digestible nutrients and the fertilizing constituents in the most important American feeds. As these tables are specially protected by copyright, they can be given in no other texts on stock feeding.

Especial thanks are due the following for assistance: Mrs. Elsie Bullard-Morrison, who has rendered invaluable aid on every page of the book; Prof. J. A. James of the Department of Agricultural Education, University of Wisconsin, and formerly Superintendent of the Racine County, Wisconsin, School of Agriculture, who has made valuable suggestions in adapting the book to the needs of secondary schools; and Prof. J. G. Halpin of the University of Wisconsin, who greatly aided in preparing the chapters on poultry. Credit is given in each instance to those loaning illustrations for use in the book.

F. B. Morrison

Madison, Wis.
August, 1921.

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FEEDS AND FEEDING, ABRIDGED

INTRODUCTION

LIVE STOCK AND PROFITABLE FARMING

Farm animals are really living factories that are continuously converting their feed into products useful to man. A most important fact is that a large part of the feed thus made useful is of such character that it cannot be directly utilized by humans. Among the products yielded by animals are such articles of human diet as meat, milk, and eggs, materials like wool, mohair, and hides, which meet other needs of man, and, of greater aggregate value than any one of these, the work performed by draft animals. The great importance of animal husbandry in the United States is shown by the fact that on January 1, 1921, the horses, mules, cattle, sheep, and swine had a total value of over $6,200,000,000.

As the population of our country increases, most naturally a smaller portion of the crops raised can be fed to animals and more will be consumed directly by humans. This change must come with the increased demand for human food, since even high-producing animals can convert but a part of their food into forms edible for man. However, until the World War caused a temporary increase in the number of beef cattle and swine in this country, due to the pressing need for more animal products for export, the number of cattle and sheep had actually been decreasing and the number of swine had increased but slightly. This means that animal products can not long hold their present important place in our diet unless American farmers come to appreciate the advantages of stock farming and better understand the principles and methods which are essential to its success.

Live-stock farming and soil fertility.—With the high prices ruling, many farmers are selling their crops for cash, rather than marketing at least a portion thru feeding them to live stock, and thereby practicing balanced agriculture. Too often they forget that each ton of grain sold removes from $8 to $10 worth of fertility from the soil, and that this gradual mining of their farms will result in worn-out fields that must forever afterwards be fed with commercial fertilizers so as to produce fair crops. On the other hand, thru feeding a part of the crops to animals and caring properly for the resulting manure, most of the fertility may be retained on the farm, and the need of commercial fertilizers long delayed. Where intensive stock farming is followed and milling by-products rich in fertilizing constituents are purchased and fed on the farm, the land may grow richer each year, with little need for commercial fertilizers.

Consumption of feed otherwise wasted.—In exclusive grain farming, there is no successful way of utilizing such materials as straw and corn stover, and, being regarded as waste, they are often burned or otherwise disposed of without regard to the fertility lost to the soil. In stock husbandry, all these by-products may be economically used for feed or bedding. By this means much forage which cannot be eaten by humans and would otherwise be wasted, is refined thru the agency of animals into forms suitable for man, while most of the fertility goes back in the manure to nourish the fields. Immense quantities of by-products result from the manufacture of flour, breakfast foods, vegetable oils, etc. Tho these are all unsuited for human food, they are valuable feeds for stock. As our population increases,

FIG. 1.—LIVE STOCK UTILIZE FEED OTHERWISE WASTED

In grain farming, the corn stalks are allowed to waste away in the fields after the ears are harvested, but in live-stock farming the corn stover is profitably fed to the stock.

such by-products must to an ever increasing degree be used to sustain farm animals.

Utilization of land unsuited for tillage.—In those sections of our country which are so rough or stony that the land cannot be cultivated, cattle and sheep may be profitably kept. Also, in the great semi-arid regions of the West where neither dry farming nor irrigation are practicable, stock thrive on the scanty but extremely nutritious grasses and other vegetation. Cut-over timber districts may likewise be profitably grazed before they are finally brought under tillage.

Distribution of labor.—In grain farming, the demand for labor is irregular and during rush seasons, such as harvesting, help is scarce and high priced. On the other hand, live-stock farming gives employment thruout the year. Moreover, in winter, when animals require the most care and attention, the farmer is the least busy with other farm work. By offering steady employment, the stock farmer is usually able to secure more efficient and trustworthy men than the grain farmer.

Intelligent and progressive agriculture.—The whole world over, the most enlightened and progressive agricultural districts are found where live-stock farming is practiced. This is due to several reasons: The live-stock farmer can not live from hand to mouth, but must lay in a store of feed for his animals thruout the winter months. This same care and foresight are then carried into his other activities. Under some systems of agriculture the returns from the year's crops all come in at once, which makes for extravagance and idleness, with resultant poverty until another crop is harvested. On the other hand, under most systems of live-stock farming, income is secured several times during the year.

The care and control of domestic animals, which are intelligent yet submissive to his will, tend to develop those instincts in man that make him kindly, self-reliant, and trustworthy. The good stockman grows proud of his sleek, well-bred animals and derives a satisfaction therefrom not measured in money. With pride he may hand down to his sons his reputation as a breeder. He is also able to leave them fertile fields which he has built up rather than robbed, a heritage bequeathed by few grain farmers.

Profitable live-stock farming.—In the early days, with land low in price, pasturage abundant, and feed and labor cheap, profit from live-stock farming was comparatively easy, even tho one knew little of the principles governing the feeding and care of stock. Conditions have now changed. The great western prairies no longer offer rich fields free for the taking, and hence thruout the country fertile land is now relatively high in price. While labor and feeding stuffs are much lower than under war-time conditions during the past few years, they are considerably higher than in early days. Therefore present times call for a more intelligent type of stock farming than has ruled in the past. Efficiency is especially necessary in making the difficult adjustments from the inflated war-time basis of costs and prices. In the long run, good profits will be realized in the future as in the past from stock farming, when the operations are planned with good judgment and with a thorough appreciation of the requirements of the various classes of animals for food and care. However, haphazard and unscientific animal husbandry should not and can not return a profit under present day conditions.

In the pioneer days of our country the feeds commonly used for live stock were restricted to the grains and forages grown on the farm. Knowledge of the value of these farm-grown products is not now sufficient for intelligent feeding. The problem is complicated by the host of by-products resulting from the manufacture of articles of human food. Many of these are valuable and economical supplements to the feeds raised on the farm. However, such products vary considerably in price and even more markedly in nutritive value. Most economical feeding is therefore possible only when the relative value of these products compared with each other and with the farm-grown crops is clearly understood.

In learning of feeds and of feeding we must first consider the plant substances which provide the nourishment for farm animals and study how they are built up in the living plant. Next we should learn how the food consumed by animals is digested and utilized within the body for the production of meat, milk, work, or wool, and should also study the requirements of each class of animals for food, water, shelter, and exercise. Only then are we in a position to understand the value and merits for each of the farm animals of the many different feeds, and finally to consider the principles of care and management, the constant observance of which is essential to the highest success in animal husbandry.

PART I

PLANT GROWTH AND ANIMAL NUTRITION

CHAPTER I

HOW PLANTS GROW AND BUILD FOOD FOR ANIMALS

I. PLANT GROWTH

All food for animals, with the exception of air, water, and salt, is supplied either directly or indirectly by plants. To understand the feeding of live stock, one should therefore know how plants grow and build this food and of what it consists.

The food of plants.—Both plants and animals are composed of a great many substances or compounds—yet all are made up of a relatively small number of chemical elements. Indeed, of the 80 or more elements known to the chemist, only 14 are commonly present in plants. Of these, at least 10 are absolutely necessary for plant growth. These are: carbon, hydrogen, oxygen, nitrogen, sulfur, phosphorus, potassium, calcium, magnesium and iron. Sodium, silicon, chlorine, and manganese are also usually found in plants and may be essential to growth. Iodin also is present in some plants. Except in the two instances which will be noted later, plants cannot use for food the uncombined elements, such as metallic iron or carbon in the form of charcoal, but they are nourished by water, carbon dioxid (carbonic acid gas), and mineral salts—all of which are compounds containing the elements in chemical combination.

Water (composed of hydrogen and oxygen) serves a double purpose in plants. Some of the water taken up by the plant roots is used as food, while the rest serves as the carrier of plant food. Only when it is dissolved in water can plant food be taken from the soil by the roots or be carried from one part of the plant to another. A surprising amount of water is needed by plants during growth. For every pound of dry matter which they manufacture, from 200 to 500 lbs. of water is drawn from the soil in humid climates, and as high as 1,800 lbs. in arid districts.

Next to water, carbon dioxid, or carbonic acid gas (composed of carbon and oxygen), is the great food material of plants. This is obtained from the air, ten thousand parts of which contain 3 to 4 parts by volume of carbon dioxid. The air supplies carbon dioxid to the cells of the plant thru the innumerable minute openings on the under surface of the leaves. In producing a 15-ton crop of green corn over 5 tons of carbon dioxid are required, to obtain which the plants must take in over 12,000 tons of air. Yet the supply of carbon dioxid is never exhausted, for it is being continuously returned to the air thru the breathing out of carbon dioxid by animals and the decay of plant and animal matter.

Nitrogen abounds in the living, growing parts of plants. Altho about three-fourths of the air is nitrogen gas, plants in general cannot use the free nitrogen of the air, but obtain their supply from nitrogen-containing compounds in the soil, chiefly the nitrates. Bacteria living in nodules on the roots of legumes, such as clover, alfalfa, and peas, are able to take nitrogen gas from the air and pass it on in combined form to the host plants. Thus, the legumes are able indirectly, thru the aid of these bacteria, to use the nitrogen of the air as food.

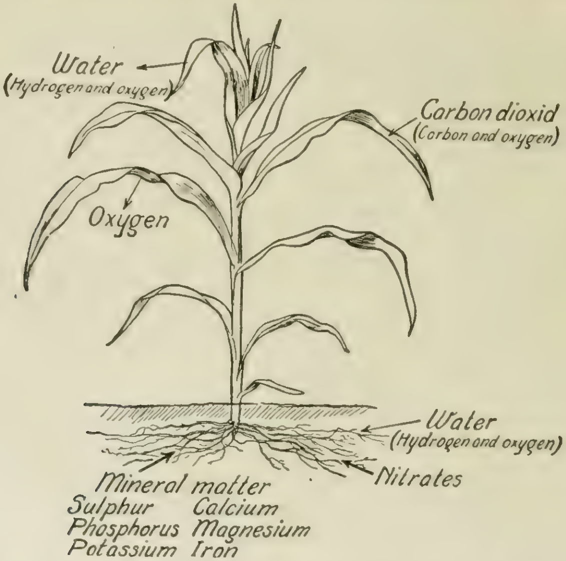

Fig. 2.—Where Plants Secure Their Food

Plants obtain carbon dioxid from the air, and water, mineral matter, and nitrates from the soil. Legumes are able to use indirectly the nitrogen of the air. Plants give off water and free oxygen gas to the air thru their leaves.

Oxygen, which is a part of all plant compounds, is obtained largely from water and carbon dioxid, and not from the free oxygen gas of the air. Some oxygen gas is, however, being continuously absorbed by all green plants and is necessary for their growth.

The mineral substances, such as phosphates, potash, and lime, which are needed by the plants, are taken from the soil thru the roots.

Plant building.—The carbon dioxid, the water, and the nitrates and other mineral compounds are carried in the sap currents to the living, green-colored protoplasm of the leaf cells. Here these relatively simple compounds are built into the much more complex plant substances. In some mysterious manner chlorophyll, the green coloring matter of the leaves, breaks down carbon dioxid and water under the influence of light, and rearranges the carbon, hydrogen, and some of the oxygen into relatively simple plant compounds. The rest of the oxygen is given back to the air as free oxygen gas. It is not definitely known whether the first product so formed is starch, sugar, or some simpler compound. From the compounds first made the plant then builds more complex substances, some of which contain mineral matter obtained from the soil. Both sugar and starch contain much energy,

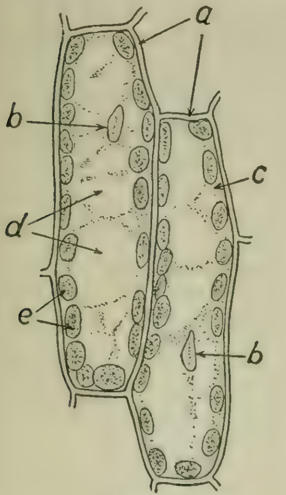

Fig. 3

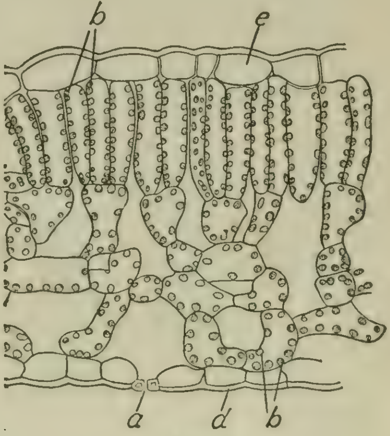

Fig. 4

Fig. 3.—Plant Cells, Magnified 350 Times

A, Cell wall; b, nucleus, or life center of cell; c, strands of protoplasm; d, spaces filled with cell sap; e, chlorophyll bodies. (After Strassburger.)

Fig. 4.—Section of Leaf, Magnified 400 Times

A, Stoma, or openings on under side of leaf thru which air enters; b, chlorophyll bodies in leaf cells; d, lower epidermal cells of leaf; e, upper epidermal cells of leaf. (After Strassburger.)

while carbon dioxid and water contain but little. Therefore, to make sugar and starch from these two energy-poor substances the plant must secure energy from some outside source. This it obtains from the sun, as light, which is absorbed by the leaves.

The carbohydrates.—Sugar and starch, together with the related products, the celluloses and pentosans, are called carbohydrates. This group of plant compounds makes up the major portion of all plant substance. The term *carbohydrates* means that these compounds are formed of the three elements, carbon, hydrogen, and oxygen, the latter two being present in the proportion existing in water, the chemical formula for which is H_2O. (This means that every molecule of water contains two atoms of hydrogen and one atom of oxygen.)

The molecular composition of the leading plant carbohydrates is as follows:

Glucose Fruit sugar	$C_6H_{12}O_6$
Cane sugar Malt sugar	$C_{12}H_{22}O_{11}$
Starch Cellulose	$(C_6H_{10}O_5)x$
Pentose	$C_5H_{10}O_5$
Pentosan	$(C_5H_8O_4)x$

The molecules in the bracketed groups are in reality far more complex than the formulæ indicate, the actual molecule being many multiples of the groups here given.

All sugars, not only the simpler *glucose* and *fruit sugar* but also the more complex *cane sugar* and *malt sugar,* are soluble in the juices of the plant. They are thus the portable, carbohydrate building material of plants, which is carried in the sap to all their parts as needed. Some plants, as the beet and the sugar cane, store their reserve food chiefly in the form of sugar.

Starch is more complex in structure than the sugars and is insoluble in water. It is the form in which most plants chiefly store their reserve food. This carbohydrate abounds in nearly all seeds, forming over 70 per ct. of the dry matter in corn and wheat grains. Often starch is stored in the underground parts of plants, as in the potato tuber, or in fruits, as in the apple. Since starch is insoluble in the sap, it must be changed into sugars by an enzyme or ferment when it is needed in other parts of the plant. (See Page 22.)

Cellulose is the great structural substance of plants, for the walls of all plant cells consist chiefly of this carbohydrate. Thus it forms almost the whole of the skeleton or framework of plants. It is built by the plant cells from the simpler carbohydrates—the starches and sugars. The thickness of the cell walls, and consequently the percentage of cellulose, varies greatly in different parts of plants, the walls being thick and resistant in the woody stems, and thin and delicate in the softer parts, such as the fruits and leaves. Especially in the woody parts of plants, the cell walls do not consist simply of pure cellulose, but of cellulose combined with other related carbohydrates, which are even tougher and more resistant. In analyzing plants the chemist includes cellulose and these other compounds under the term *fiber*.

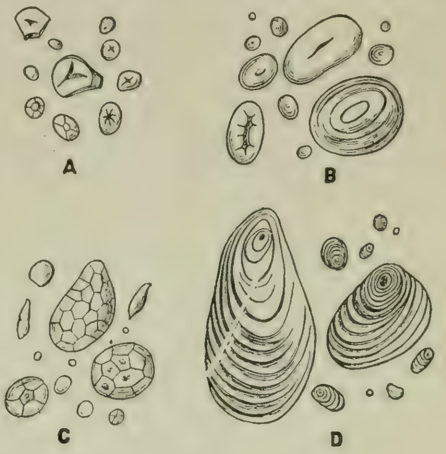

FIG. 5.—STARCH GRAINS

A, From corn grain; b, from wheat; c, from oats; d, from potato. (Magnified 330 times.)

The *pentoses* and *pentosans* are carbohydrates with 5 atoms of carbon in the molecule, in place of 6 as in the sugars and starches. The pentoses correspond to sugars, and the pentosans to starch and cellulose. The pentosans are widely distributed in plants, being found in largest amount in the more woody portions and in the outer portions of seeds. While corn grain contains less than 6 per ct. of pentosans, straw and hay from the grasses usually contain over 20 per ct.

Fats and oils.—*Fats,* which are solid at ordinary temperatures, and *oils*, which are liquid, are composed of the same elements as are the carbohydrates; i. e., carbon, hydrogen, and oxygen. In fats and oils, however, the proportion of carbon and hydrogen is greater. They therefore give off more heat on burning, one pound of fat producing about two and a quarter times as much heat as a pound of carbohydrates. Oils and fats most abound in the seeds of plants, the reserve food supply in peanuts and flax seed, for example, being largely in this form.

Nitrogenous compounds.—In the living plant cells sugar and starch, formed from carbon dioxid and water thru the action of the sunlight, are united with nitrates and other salts gathered by the roots from the soil to form a new group of complex compounds called *crude proteins.* In addition to carbon, hydrogen, and oxygen, these compounds contain nitrogen, sulfur, and sometimes phosphorus. The nitrogenous compounds are the most complex of all plant compounds and are therefore the most difficult to study and classify. For example, the probable molecular composition of legumin, a protein found in the seed of the field pea, is $C_{718}H_{1158}O_{238}N_{214}S_2$. Due to this complexity, and also because of the great number of different nitrogenous compounds found in plants, even after years of effort by able chemists our knowledge of the differences in composition and feeding value of these compounds is still limited. In discussions of feeding stuffs and stock feeding, the terms *crude protein, protein,* and *amids* are commonly used for designating the various classes of nitrogenous compounds.

Crude protein includes all the nitrogenous compounds of the plant. The chemist finds that about 16 per ct. of the plant proteins is nitrogen. Accordingly, he multiplies the nitrogen found in a given plant substance by 6.25 ($100 \div 16 = 6.25$) and calls the product crude protein. Crude protein embraces two great groups of nitrogenous plant compounds, *proteins* and *amids.*

The *amids* may be termed the building stones of the proteins, for from them the plant constructs the more complex proteins, just as a wall is built from stones, and on decomposition the proteins are again broken down into these more simple substances. These compounds are the portable nitrogenous building compounds of the plant, for they are soluble in its juices and hence may be carried wherever needed. Commonly included under the general term amids are compounds which the chemist calls *amino acids,* and others which he terms *true amids.* In this book, unless otherwise stated, amids will be used to denote both classes of substances.

Proteins are the more complex forms of crude protein. They are not always soluble, and therefore in many cases not transportable, in the juices of the plant. The proteins form the basis of the protoplasm, which is the life-holding part of all plants and animals, and so are essential to all life.

The complexity of the proteins is evident from the fact that 18 different amino acids have already been identified which may enter into their composition. Just as the letters of the alphabet may be combined into innumerable words, so the possibility for the combination of the amino acids into different proteins is almost limitless. Thus far, scores of different plant and animal proteins have been separated and examined by the chemists. Some of these, such as egg albumin, contain all the known amino acids, while others, as zein of corn and gliadin of wheat, lack one or more of them. As will be shown later, the incomplete proteins may have a lower value for animal feeding than those which are complete.

During the growth of the plant, amids are constantly being formed in the living cells out of sugar or starch and the nitrates and other mineral salts. These amids are continually being carried to needed points and there changed into the proteins, and as a consequence do not usually accumulate in the plant. Just as starch and sugar are changed one into the other in the plant, so the proteins and amids may be changed one into the other as plant necessity may require. When germination starts in a seed, an enzyme, or ferment, it contains acts on the insoluble proteins stored in and about the germ and changes them to soluble amids, so that the nitrogen may be transferred to the newly forming parts of the plantlet. But little crude protein is found in the older, woody parts of plants, the greater portion always being concentrated at the points of growth; i. e., in the leaves, flowers, and seeds.

Plants support animal life.—It is Nature's plan that plants shall use energy supplied by the sun in building inorganic matter taken from earth and air into organic compounds. In this process the sun energy employed becomes latent, or hidden. Animals can not directly secure from the sun the energy necessary for their life but must live on the organic compounds built by plants. After more or less change during digestion, these compounds are built into their body tissues or are broken down within their bodies to produce heat and energy. In the coal burning in the grate, there reappears the energy of the sun which was stored in the plants of ages ago. In a similar manner the energy received from the sun by plants during their growth is transformed into animal heat and energy. Plants are thus sun-power machines for furnishing food to support animal life.

II. How the Chemist Groups Plant Substances

As we have seen, many different compounds are formed in plants, some of these being so complex that their exact structure has not yet been determined. In studying feeding stuffs it is desirable to group all plant compounds into a few classes, the amounts of which can be readily found by chemists. Accordingly, in analyzing plant materials and feeding stuffs, the following classes or groups of substances are commonly determined: water, ash or mineral matter, crude protein, fiber, nitrogen-free extract, and fat. The average percentages of these in typical feeds are shown in the following table, which is taken from Appendix Table I. The last column gives the number of analyses from which the average composition has been computed by the authors.

Chemical composition of typical feeding stuffs, from Appendix Table I

Feeding stuff	Inorganic matter		Organic matter				
				Carbohydrates			
	Water	Ash	Crude protein	Fiber	N-free extract	Fat	No. of analyses
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Concentrates—							
Dent corn	10.5	1.5	10.1	2.0	70.9	5.0	440
Oats	9.2	3.5	12.4	10.9	59.6	4.4	490
Wheat	10.2	1.9	12.4	2.2	71.2	2.1	858
Wheat bran	10.1	6.3	16.0	9.5	53.7	4.4	7,742
Flax seed	9.2	4.3	22.6	7.1	23.2	33.7	50
Roughages—							
Timothy hay	11.6	4.9	6.2	29.9	45.0	2.5	221
Red clover hay	12.9	7.1	12.8	25.5	38.7	3.1	76
Oat straw	11.5	5.4	3.6	36.3	40.8	2.4	41
Kentucky bluegrass	68.4	2.8	4.1	8.7	14.8	1.2	32
Corn silage	73.7	1.7	2.1	6.3	15.4	0.8	121
Mangels	90.6	1.0	1.4	0.8	6.1	0.1	38

Water.—To determine the amount of water in a feed, the chemist weighs a sample before and after drying in an oven at a temperature of 212° F. for several hours. Volatile compounds, such as give various plants their characteristic odors, are driven off in addition to the water by heating, but their weight is insignificant. The table shows that even such "dry" feeds as corn, oats, wheat, and wheat bran contain 9 per ct. or more of water. Timothy and clover hay contain still more water, and such succulent feeds as green grass, corn silage, and mangels are largely water.

Ash, or mineral matter.—The chemist next burns the sample and finds the weight of ash, or mineral matter, which is left. The table shows that 100 lbs. of corn or wheat contains less than 2 lbs. of ash, while oats, with their strawy hulls, and wheat bran, consisting of the outer coats of the wheat grain, carry more. The hays and straws are higher in ash than such grains as corn and wheat, due to the accumulation of mineral matter in the leaves during growth, to soil washed upon the growing plants by rain, and to dust settling on the roughage before it is housed. Such foreign material is not really plant ash, but of necessity is reported as such. Owing to their high water content, the ash in 100 lbs. of fresh grass, silage, and mangels is low.

The ash and water of plants together constitute the so-called *inorganic matter;* the other compounds—crude protein, carbohydrates, and fat—are termed the *organic matter.*

Crude protein.—The process of determining the nitrogenous constituents of feeding stuffs is too complicated for presentation here. Suffice it to say that the nitrogen content is found, and the result multiplied by 6.25 to give the crude protein, since about 16 per ct. of plant protein is nitrogen ($100 \div 16 = 6.25$). From the table we learn that 100 lbs. of wheat bran contains 16.0 lbs. of crude protein, while the amount in wheat is 12.4 lbs. and in dent corn only 10.1 lbs. per 100 lbs. Red clover hay contains over twice as much crude protein as timothy hay.

Fiber.—The woody portion of a feeding stuff is determined by boiling a sample successively in weak acid and alkali and washing out the dissolved matter. That which remains is termed *fiber*. Fiber, which consists mostly of cellulose, is less digestible and hence has a lower nutritive value than the other nutrients of feeding stuffs. Corn contains but 2.0 and wheat only 2.2 per ct. of fiber, while, owing to the woody hulls, oats contain 10.9 per ct. Most roughages, especially the straws, are much higher in fiber than the concentrates. Mangels contain but 0.8 per ct. fiber; were they dried to the same water content as oats they would contain only 7.7 per ct. fiber—less than oats.

Fat.—A sample of the pulverized dried fodder is treated with ether, which dissolves out the fats and also the waxes and resins, the chlorophyll, or green coloring matter, and similar substances. This, called *ether extract* in works on plant analysis, is for convenience termed *fat* in this work. The ether extract of seeds is nearly all true fat or oil, while that of the leaves and stems of plants contains much chlorophyll, wax, etc. Corn and oats carry more fat than the other cereals. Some seeds, such as flax seed, are so rich in oil that it may be extracted from them by crushing and subsequent pressure.

Nitrogen-free extract.—The *nitrogen-free extract*, expressed in the tables in this book as *N-free extract*, embraces the substances that are extracted from the dry matter of plants by treatment with weak acids and alkalies under standard conditions, less the crude protein, fat, and ash. It is determined by difference and not by direct analysis. The total dry matter in a feeding stuff minus the sum of the ash, crude protein, fiber, and fat, equals the nitrogen-free extract. It embraces the sugars, starches, pentoses, non-nitrogenous organic acids, etc., of the plant. The nitrogen-free extract is more soluble and hence more digestible than the fiber, and thus has a higher nutritive value. Over 70 per ct. of both corn and wheat is nitrogen-free extract, largely starch. The roughages, carrying much woody fiber, contain less of these more soluble carbohydrates than the concentrates. The nitrogen-free extract and fiber together constitute the *carbohydrates*.

Roughages and concentrates.—These terms are used to differentiate feeding stuffs of a coarse, bulky nature from those which are more condensed and nutritious.

Concentrates are feeding stuffs of condensed nature, which are low in fiber and hence furnish a large amount of digestible matter. Examples of this class of feeds are the various grains, as Indian corn, wheat, and oats, and milling by-products of high feeding value, as wheat bran, linseed meal, gluten feed, etc.

Roughages are the coarser feeding stuffs, which are high in fiber and supply a lower percentage of digestible matter. Such feeds as hay, corn fodder, straw, and silage belong to this class. Some of the low-grade milling by-products, such as oat hulls, ground corncobs, and peanut hulls are roughages, rather than concentrates, for they are largely fiber and furnish but little nutriment. Roots are watery and bulky, and contain relatively little nutriment per pound, yet based on the composition of the dry substance they are more like concentrates than roughages, as they are low in fiber. They are really watery, or diluted, concentrates, tho for convenience they are included under fresh green roughages in Appendix Table I.

III. THE STUDY OF AN ACRE OF CORN

The manner in which plants grow and store nutrients is well shown by a study of Indian corn, the greatest of our agricultural plants.

Changes in a growing corn crop.—By analyzing corn plants at various stages from July 24, when they were about 4 ft. high, until Oct. 8, when the kernels were hard, Jones of the Indiana Station[1] secured the following data, based on an average stand of 10,000 stalks per acre.

Composition of an acre of Indian corn at different stages

Stage of growth	Total wt. of green crop	Dry matter in crop	Ash	Crude protein	Fiber	N-free extract	Fat
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Four feet high, July 24	5,138	731	90	149	170	282	40
First tassels, Aug. 6..	18,827	2,245	195	360	670	977	42
Silks drying, Aug. 28..	24,327	4,567	272	436	1,203	2,606	49
Milk stage, Sept. 10 ..	26,710	6,174	328	544	1,361	3,846	95
Glazing stage, Sept. 24	25,750	8,104	389	566	1,523	5,425	202
Silage stage, Oct. 1...	25,275	8,929	369	660	1,602	6,084	215
Ready to shock, Oct. 8.	22,253	9,412	383	691	1,737	6,336	265

From July 24, at a stage when sometimes unwisely fed as soilage, to Aug. 28, when the silks were drying, the crop increased over 19,000 lbs. in total weight and nearly 4,000 lbs. in dry matter. The increase in total weight was thereafter less rapid, reaching the maximum when the kernels were in the milk stage. After this the gross weight decreased by over 4,000 lbs., due to drying out as the crop matured. The dry matter, however, continued to increase rapidly until the plants were fully ripe. Indeed, in less than a month following Aug. 28 the acre of corn stored over 3,500 lbs. of dry matter! When four feet high the crop was nearly 86 per ct. water and only 14 per ct. dry matter; while when the kernels were hard and the husks dry over 42 per ct. was dry matter. The mineral matter, or ash, increased rapidly until the plants reached their full height.

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[1] Ind. Bul. 175; see also Ladd, N. Y. (Geneva) Rpt. 1889.

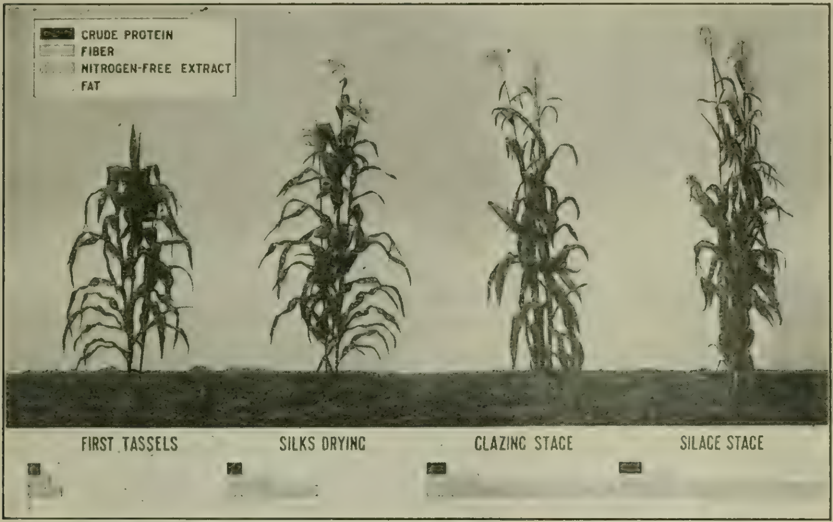

Fig. 6.—Nutrients in Corn Plants at Various Stages

The shaded areas in the legend represent the amount of crude protein, fiber, nitrogen-free extract, and fat in corn plants at various stages. (From Indiana Station.)

The most rapid increase in crude protein, the nitrogenous portion, occurred in the period before the plants were tasseled, when cell growth was most active, but some increase occurred until the plants reached maturity. Altho amids—the building-stones of the proteins—were constantly being formed during the development of the plants, they were in turn quickly built over into the more complex, stable proteins. Hence it was found in further studies that the amount of amids did not increase after the plants were silked, while there was a steady storage of true protein up to maturity.

Since the stalk of the corn plant must be strong and sturdy to carry the abundant foliage and the heavy ear, the fiber increased rapidly until the woody framework was grown.

The table shows that the nitrogen-free extract, the most valuable portion of the carbohydrates, made up of sugars, starch, and the other more soluble carbohydrates, increased more than 2.5 tons between tasseling and ripening. This increase was chiefly starch, for, altho sugars were being steadily formed in the leaves of the plants, they were being continuously transferred to other parts, especially the swelling kernels of the ear, where they were changed to starch. Another portion of the sugars was changed into cellulose to form the woody framework of the plant structure. The elements of a third portion were combined with nitrates and other mineral matter from the soil to form the nitrogenous amids and proteins.

At the milk stage, starch formed less than a fifth of the nitrogen-free extract, but after this it increased rapidly as it was stored in the maturing kernels. From the milk stage to the date when the corn was ready to shock, less than a month, there was a gain of nearly 2,500 lbs. of nitrogen-free extract, over a ton of which was starch. This shows plainly the heavy losses of valuable nutrients which occur when a crop of corn is harvested too early.

In producing this acre of corn, probably not over 10 lbs. of seed was placed in the ground in the spring time. From this insignificant beginning, by the following October, about 130 days later, the resultant plants had gathered inorganic matter—carbon dioxid from the air, and water, nitrogen, and mineral matter from the soil—and built all these, first into primary organic forms, and finally into complex organic parts of their structure. The product of such building amounted to over 11 tons of green or 4.7 tons of dry matter, nearly all available for nourishing the animals of the farm and, thru them, man. This is a forceful illustration of Nature's wonderful processes of food production occurring all about us under the guiding hand of man.

The end of plant effort.—In the life of the plant, we find that the first effort is toward self-establishment and enlargement. At this time all the material formed in the plant is transferred to the growing parts. As the plant approaches maturity, its energies are changed from growth to reproduction, or the formation of seed. For example, in the corn plants the nutrients are now poured in a steady current into the ear, where the kernels rapidly develop. In each of these grains is the germ—a miniature plant—composed largely of protein, about which is stored a generous supply of rich nutrients—proteins, starch, sugar, oil, and mineral matter—all in compact, concentrated form after Nature's choicest plan, to nourish the new life which is to follow if the kernel finds lodgment in the soil.

QUESTIONS

1. Name the 10 elements essential for plant growth and 4 others which are commonly found in plants.

2. Make a sketch of a growing plant, showing where it secures each essential element.

3. How do legumes indirectly use free nitrogen gas from the air?

4. How are the first simple plant compounds formed?

5. Define carbohydrates. State what classes of compounds are included in this group and tell what you can about each.

6. How do fats and carbohydrates differ in composition?

7. Distinguish between crude protein, proteins, and amids.

8. Why do not the amids accumulate in the plant during its growth?

9. In analyzing feeding stuffs, what groups of plant substances do chemists usually determine?

10. How is the amount of each found?

11. What is meant by concentrates and roughages?

12. Discuss the storage in the growing corn plant of the various nutrients, especially the carbohydrates.

CHAPTER II

THE ANIMAL BODY—DIGESTION—METABOLISM

I. The Composition of the Animal Body

Having studied the composition of plants and the manner in which they grow, let us now study the composition of the bodies of farm animals, which are nourished by plants.

The animal body.—The bodies of the higher animals consist of a bony skeleton, chiefly of mineral matter, surrounded by an elaborate muscular system. Fatty tissue permeates the bones and muscles, filling in and rounding out the body form, and around all is the enveloping skin. Within the body cavity are the various special organs, such as the heart, stomach, etc., designed for dissolving, distributing, and utilizing the nutrients of the food and for disposing of the waste. All these organs are nitrogenous or protein in nature, as are also a part of the organic matter of the bones and a large portion of the nerves, which control and direct all body activities.

Therefore, one of the fundamental differences between plants and animals is that in animals the walls of the body cells are made chiefly of protein, while in plants the walls of the cells are composed of cellulose, which is a carbohydrate. Furthermore, in plants starch, another carbohydrate, is the chief form in which reserve food is stored. In animals, on the other hand, nearly all the reserve food is stored in the form of fat. Tho small amounts of glucose and glycogen, or animal starch, perform important functions in the bodies of animals, as we shall see later in this chapter, these carbohydrates at no time form an appreciable part of the animal's weight.

Composition of animals.—Over 60 years ago Lawes and Gilbert, the famous English agricultural scientists, analyzed the entire bodies of several farm animals—a task involving much labor. During recent years similar studies have been made at certain of the American experiment stations. The following table,[1] which summarizes some of these investigations, shows that the composition of the bodies of farm animals varies greatly according to their age and degree of fatness:

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[1] Data for cattle from Haecker, Proc. Amer. Soc. Anim. Prod., 1914, and for sheep and swine from Lawes and Gilbert, Philosophical Transactions, 1859.

Composition of the bodies of farm animals *

	Water Per ct.	Protein Per ct.	Fat Per ct.	Ash Per ct.
Calf, wt. 100 lbs.	71.8	19.9	4.0	4.3
Calf, wt. 300 lbs.	66.3	19.0	10.2	4.5
Growing steer, wt. 700 lbs.	60.3	18.6	16.6	4.5
Partly fat steer, wt. 1,000 lbs.	53.0	17.6	25.6	3.8
Fat steer, wt. 1,200 lbs.	48.6	16.6	31.1	3.7
Very fat steer, wt. 1,500 lbs.	43.5	15.7	37.7	3.2
Fat lamb	52.3	13.4	31.2	3.2
Sheep, before fattening	61.0	15.7	19.9	3.4
Half-fat sheep	55.2	15.4	25.9	3.5
Fat sheep	46.2	13.0	37.9	3.0
Very fat sheep	37.1	11.5	48.3	3.1
Hog, before fattening	58.1	14.5	24.6	2.8
Fat hog	43.0	11.4	43.9	1.7

* Not including contents of digestive tract.

The table shows that 71.8 per ct. of the body of a 100-lb. calf is water and that the proportion of water steadily grows less as the animal matures and fattens, the body of a very fat 1,500-lb. steer containing only 43.5 per ct. water. The percentage of protein remains quite constant during growth but decreases as the animal fattens. On the other hand, the percentage of fat increases gradually during growth, and more rapidly while fattening. Over one-third of the carcass of the fattened 1,500-lb. steer is fat. The percentage of ash, or mineral matter, shows the least change, but decreases as the animal fattens, since the fatty tissue contains but little mineral matter. Similar changes occur in the bodies of sheep and swine as the animals mature and fatten. In general, the bodies of sheep and swine at the same degree of fatness contain less water and protein and considerably more fat than those of cattle. The fat hog, for example, contains 43.9 per ct. fat and only 11.4 per ct. protein. Due to their small skeletons, the bodies of swine contain less ash than those of cattle and sheep.

II. DIGESTION

The changes which food undergoes within the digestive tract of animals to separate the useful portion from the waste matter and prepare it for absorption and final use in the body are known as *digestion*.

Nutrients and rations.—In discussing stock feeding it is necessary to understand clearly what is meant by each of the following terms:

The term *nutrient* is applied to any food constituent or group of food constituents of the same general chemical composition, that aid in the support of animal life. Crude protein, the carbohydrates, and fat constitute the generally recognized classes of nutrients, altho air, water, and mineral matter might likewise be so termed.

The term *digestible nutrient* covers that portion of each nutrient which may be digested and taken into the body.

A *ration* is the feed allowed for a given animal during a day of 24 hours, whether all is fed at one time or in portions at different times.

A *balanced ration* is one which furnishes the several nutrients—crude protein, carbohydrates, and fat—in such proportion and amount as will properly nourish a given animal for 24 hours.

The alimentary canal.—The alimentary canal is a long, tortuous tube passing thru the animal from mouth to vent, enlarged in places for the storage of food or waste. It includes the mouth, gullet, stomach, small intestine, and large intestine. Within its linings are organs which secrete the various fluids of digestion, and into it, from other organs located near by, pour still other digestive fluids. Within its walls are nerves controlling its action, arteries which nourish it with fresh blood, and veins and lymphatics which absorb and carry from it the products of digestion.

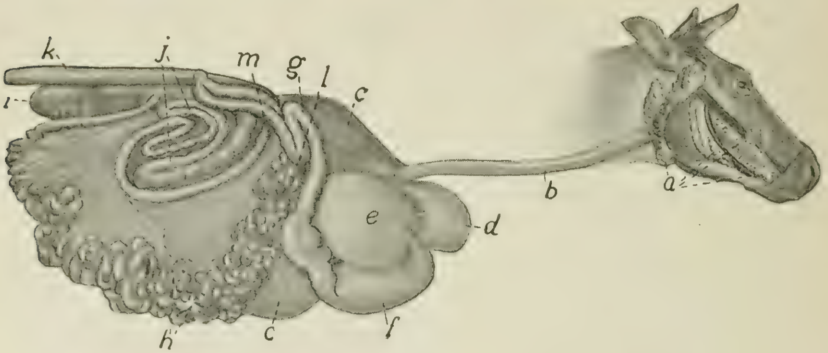

FIG. 7.—DIAGRAM OF THE DIGESTIVE TRACT OF THE COW

A, Salivary glands; b, gullet; c, paunch, or first stomach (Only a small part of the paunch is here visible, the rear portion being hidden by the intestines); d, honeycomb, or second stomach; e, manyplies, or third stomach; f, fourth, or true stomach; g, duodenum, or first part of small intestine; h, mesenteric part of small intestine; i, caecum; j, colon; k, rectum; l, point of entrance of bile duct into duodenum; m, point of entrance of pancreatic duct into duodenum. The intestines are spread out somewhat in this diagram.

Ruminants (animals which chew the cud), including the ox, sheep, and goat, have much more complicated digestive tracts than other animals. In the horse and pig the gullet is a simple muscular tube passing from the mouth to the stomach. In ruminants the gullet is expanded just before the true stomach is reached into three compartments of great aggregate capacity, the first and by far the largest of which is the paunch; the second, the honeycomb; and the third, the manyplies. The 4 stomachs of a full grown steer may hold over 250 quarts, while the single stomach of a horse holds only 12 to 19 quarts, and of a pig about 8.5 quarts.

The small intestine is the long, folded, tortuous tube into which the stomach empties. It is about 130 ft. long in mature cattle, 70 ft. in horses, 80 ft. in sheep, and 60 ft. in swine. Its average capacity is about as follows: cattle, 70 quarts; horse, 50 to 65 quarts; sheep and swine, 10 quarts. The large intestine, into which the small intestine empties, is larger in diameter but much shorter. In the horse, that part of the large intestine next to the small intestine, called the blind gut, or caecum, is greatly enlarged. Due to this, the large intestine of this animal holds from 120 to 140 quarts. Were it not for this caecum, the horse would be unable to consume and digest large amounts of roughage. In cattle the large intestine has a capacity of about 40 quarts, and in sheep 6 quarts. The pig, which has neither the 4 stomachs of the ruminants nor the large caecum of the horse, is not well fitted to use large amounts of roughage. His large intestine, however, holds nearly twice as much as that of the sheep, which aids him somewhat in disposing of coarse feed.

Mastication.—In the mouth the food is crushed and ground by the teeth and at the same time moistened by the alkaline, somewhat slimy, saliva, moist and slippery masses being formed which pass readily thru the gullet into the stomach. Exceedingly large amounts of saliva are secreted by the larger farm animals, especially when eating dry feed. For example, a horse may secrete as much as 90 lbs. during 24 hours.

Ruminants while eating chew their food only enough to moisten it. if dry, and form it into masses of suitable size to be swallowed. The gullet of ruminants opens into the first 2 stomachs thru a slit called the esophageal groove, which has an exceedingly important function. When the ox swallows the masses of solid food, which are so large as to distend the gullet, on coming to the slit they are pressed out thru it, just as would be the case if one tried to force thru a rubber tube with a slit in it an object like a ball which fitted it tightly. These masses of food usually pass into the paunch until it is full, and then on into the honeycomb instead. When hunger is satisfied the animal seeks a quiet place and proceeds to ruminate, or "chew the cud." By contractions of the muscular paunch, the honeycomb, and of the gullet itself, the food is forced back to the mouth in "cuds." Here each cud is thoroly chewed and saliva is added until the material becomes more or less souplike. On being reswallowed, this finely divided material usually flows along the gullet past the slit, and directly into the third stomach, from which it passes into the fourth, or true stomach. Water or liquid food, when first swallowed, may not be forced thru the slit into the paunch but may pass at once to the third stomach.

Enzymes.—As most of the changes which food undergoes in digestion are effected thru enzymes, their general nature should be clearly understood. *Enzymes* are mysterious organic compounds which are able to change or break down other organic compounds without themselves being changed or broken down. To illustrate the action of enzymes, we will take ptyalin, the enzyme contained in the saliva, that converts the starch of the food, which is insoluble, into sugar, which is soluble. If starch is mixed with saliva and the whole kept at body temperature, the starch gradually dissolves, being changed to sugar. Thru the action of the ptyalin, the complex starch molecule has been cleaved, or split, into the simpler molecules of sugar. If starch is mixed merely with water, instead of saliva, this change will not occur.

The ptyalin is not itself altered by this process, for, if more starch is added and the resulting sugar removed, the process may be repeated many times. However, heating the enzyme above a certain temperature destroys it. At freezing temperature its action ceases, tho the enzyme is not destroyed, for on warming it becomes active again. Ptyalin acts best in a neutral or slightly alkaline solution and is destroyed by the presence of much acid, while some other enzymes act only in acid solutions. Each of the enzymes of digestion is capable of acting on only one of the groups of nutrients—on proteins, on carbohydrates, or on fats.

Digestion in the mouth.—Not only is the food prepared for swallowing in the mouth, but in most animals the first step in digestion occurs here, thru the action of ptyalin on the starch in the food. The saliva of cattle and dogs, however, contains little or no ptyalin, and that of horses but little. The saliva of swine contains a fair amount, and that of man, monkeys, rabbits, rats, and mice has the greatest starch digesting power.

Digestion in the simple stomach.—With such animals as the horse and pig, which have simple stomachs, the food passes directly from the mouth thru the gullet to the single stomach. The glands in the walls of the stomach secrete the digestive fluid called *gastric juice.* This contains the enzymes pepsin and rennin, and from 0.2 to 0.5 per ct. of hydrochloric acid. If the food became acid as soon as it reached the stomach the action of the ptyalin of the saliva would cease at once. However, the first part of the stomach does not secrete any acid, and so the action of the ptyalin on starch continues in this part of that organ. The intestinal or rear end of the stomach, on the other hand, secretes much acid. Here the action of the ptyalin ceases and pepsin digestion becomes active.

Pepsin, which acts only in weak acid solutions, converts the very complex proteins into soluble and simpler, tho still complex, products known as proteoses and peptones. *Rennin*, the other enzyme of the gastric juice, changes milk into a solid curd. Were it not for this, milk would pass on quickly into the small intestine before its proteins had been digested by pepsin.

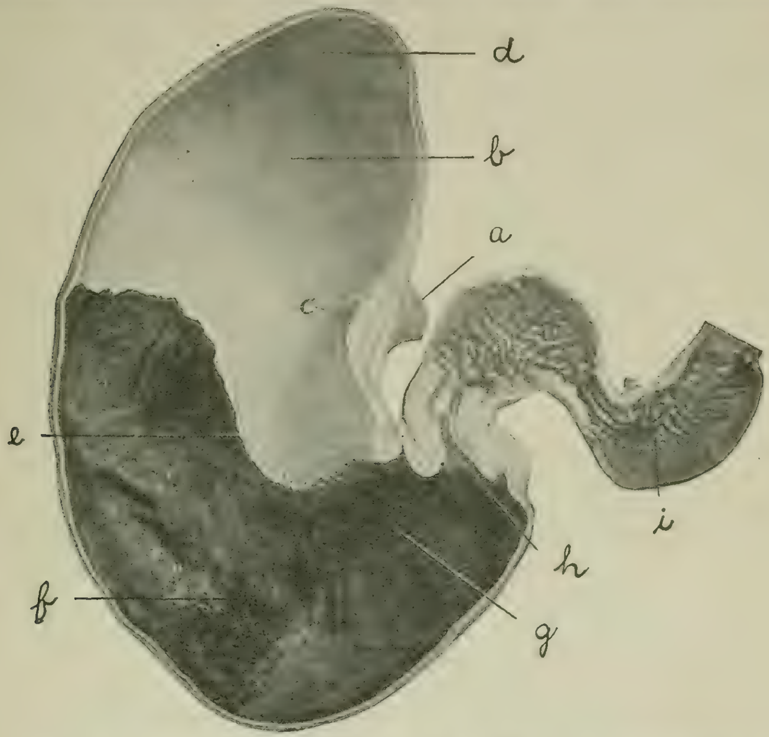

FIG. 8.—LONGITUDINAL SECTION OF STOMACH OF THE HORSE

A, Œsophagus, or gullet; b, œsophageal region of stomach, in which no gastric juice is secreted; c, entrance of gullet; d, left extremity of stomach; e, boundary between œsophageal region and portion of stomach secreting gastric juice; f. g, fundus gland region and pyloric gland region, in which gastric juice is secreted; h, pylorus, or ring of muscles closing the stomach; i, entrance of pancreatic and bile ducts. (From Sisson, "Anatomy of the Domestic Animals.")

Soon after the food reaches the stomach, its walls begin a series of regular contractions which pass in waves toward the intestinal end. When digestion has progressed sufficiently, as a contraction reaches the rear end of the stomach, the ring of muscles which keeps the stomach shut off from the small intestine relaxes and allows a small quantity of the semi-liquid contents of the stomach to spurt thru into the intestine. After this the ring of muscles again contracts, closing the entrance. The stomach now slowly relaxes, and soon the process is repeated. By this means the fluid matter is squeezed out and carried into the small intestine, while the more solid portions remain behind for further action by the gastric juice. Little or no digestion of fat takes place in the stomach.

Stomach digestion of ruminants.—Tho the first three stomachs of ruminants secrete no enzymes, but only water, they are highly important in digestion. The nutrients of plants are enclosed within the cell walls, and where these are of hard, thick cellulose, as in hay and straw, the digestive fluids can not easily reach and attack the nutrients locked within. As we have seen, when ruminants swallow solid food it passes chiefly into the paunch. Here it is softened by the moisture, slowly but thoroly mixed by muscular contractions, and ground against the rough lining. All this prepares the food for easy digestion farther on.

A considerable amount of actual digestion also occurs in these first stomachs, especially in the paunch, thru the action of bacteria. The bacteria attack the cellulose and pentosans of the feed (for which Nature has provided no other means of digestion) and break them down with the production of heat and the formation of organic acids and of gases, including marsh gas, carbon dioxid, and hydrogen. The acids serve as food, the same as do the sugars, but the gases are useless and are excreted. In this bacterial action the cell walls of the feed are broken down, setting free the nutrients contained within. Not only do the bacteria digest cellulose and pentosans, but they may also attack starch and sugar. This action is detrimental, for these nutrients would be digested more efficiently later on in the small intestine, while in the bacterial digestion a considerable part of their feeding value is lost thru the heat and gases produced in the fermentations. When fresh, easily fermented forage, such as green clover or alfalfa, is eaten, the bacterial action may then be so great that gas is produced faster than it can be carried away, and ''bloat'' results.

After rumination, the reswallowed food passes chiefly into the manyplies, or third stomach, where it is further ground between the muscular folds before being forced into the fourth, or true stomach. In the latter the digestive processes are similar to those in the simple stomach, as previously described.

Digestion in the small intestine.—When received into the small intestine, the partially digested food is a semi-liquid mass. As yet, the fats in the food have not been digested, and the digestion of the proteins and carbohydrates is far from complete. Here the work of digestion proceeds even more vigorously than in the stomach, all classes of nutrients being attacked. The small intestine receives near its upper part digestive fluids from two outside organs, the liver and the pancreas, and another digestive juice is secreted in the wall of the intestine itself. Immediately on entering the small intestine the inpouring material is changed from an acid to an alkaline character thru the rapid addition of bile and pancreatic juice, both alkaline. This stops the action of the pepsin, which works only when acid is present.

The pancreatic juice.—The pancreatic juice is produced by the pancreas, or sweetbread, a slender gland lying just beyond the stomach and connected with the small intestine by a duct. The chief enzymes it contains are trypsin, amylase, and lipase. *Trypsin,* like pepsin, changes protein into proteoses and peptones, and is also able to break some of these partially digested substances further into amino acids. It is believed that before the food protein can be absorbed and used by the animal body it must all be cleaved into amino acids, which, as we have seen in Chapter I, are the simple ''building stones'' from which proteins are formed. *Amylase* changes starch into sugar. *Lipase* splits fats into fatty acids and glycerin. The fatty acids unite with alkalies in the bile to form soaps, and are absorbed from the intestine in this form.

The bile.—The bile, secreted by the liver, the largest organ in the body, is a greenish or golden colored fluid, alkaline and extremely bitter in taste. It contains no enzymes but is nevertheless exceedingly important in digestion, as it furnishes the alkalies necessary to change the fatty acids formed by lipase into soaps. It also aids in emulsifying the undigested fat; i. e., breaking it up into very minute droplets, so that it can be more readily acted on by the lipase. Furthermore, in some manner the bile increases the digestive power of the pancreatic juice and is thot to act as an antiseptic. After performing its work much of the bile is absorbed from the intestine and, passing back to the liver, is used once more.

The intestinal secretion.—The digestive fluid secreted by the mucous membrane of the small intestine contains several enzymes, the most important of which are erepsin and the invertases. *Erepsin* attacks the proteoses and peptones which have escaped the action of trypsin and breaks them up into amino acids. It can not act on protein which has not already been split into proteoses and peptones. The *invertases* (sucrase, maltase, and lactase) change cane sugar, malt sugar, and milk sugar into the simpler glucose-like sugars.

Due to the vigorous action of the enzymes in the small intestine, digestion is very thoro and under ordinary conditions little that is useful is lost. The larger portion of all the digested matter is absorbed from the small intestine, thus entering the body proper, as is shown later in this chapter.

The large intestine.—From the small intestine the undigested material passes into the large intestine. Little, if any, digestive fluid is produced here, but a small amount of digestion may go on owing to digestive enzymes carried in from the small intestine and to the action of bacteria. The bacteria may not only attack cellulose but also may cause the putrefaction of undigested protein, in which action foul-smelling substances are formed which are poisonous if absorbed in large quantities. The waste, or feces, is finally expelled from the large intestine. Besides undigested matter, the feces contain residues of the digestive juices and countless bacteria or their remains. If the large intestine is not functioning normally, the contents may remain for an undue time, and excessive putrefaction may take place, injuring the animal thru the absorption of the poisonous products formed.

Special provision for the horse.—As has been mentioned before, the horse has a large caecum, or blind gut, in partial compensation for its small stomach and lack of a paunch. The incompletely digested matter from the small intestine, together with the enzymes mixed with it, passes into the caecum. Here the enzyme action continues and the cellulose of the feed is also attacked and digested by bacteria, as in the paunch of ruminants. Due to this, the horse is able to digest such feeds as hay and straw quite thoroly, tho less completely than can cattle and sheep.

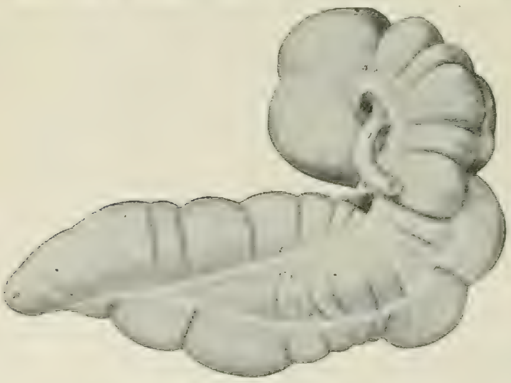

FIG. 9.—CAECUM OF HORSE

The entrance of the small intestine is designated (I). The opening of the cæcum into the large intestine is hidden from view. (From Sisson, "Anatomy of the Domestic Animals.")

Palatability.—The palatability of feeds is a factor of no small importance in the feeding of stock. Experiments have shown that the mere sight or smell of well-liked food will cause a marked flow of saliva and even cause some flow of the gastric juice. It is reasonable to believe, therefore, that well-liked feeds are digested better than others which may be equally nutritious but are less palatable.

Even with farm animals palatability is greatly influenced and controlled by familiarity and habit or custom. When corn silage is first placed before cows, not infrequently, after sniffing it, they will let it alone for a time. They then usually begin nibbling at it, and later may gorge themselves thereon if permitted. In such cases food that at first seems unpalatable becomes palatable.

In his early experience the senior author was feeding two lots of fattening steers, one on shelled corn and the other on shelled corn ground into meal, both receiving wheat bran in addition. After some weeks of successful feeding, the rations for the two lots were reversed. The steers changed from corn meal to whole corn showed a strong dislike for the new ration, eating so little at first that they shrank in weight. From this the general conclusion might have been drawn that shelled corn is less palatable than corn meal for fattening steers. But the steers given corn meal in place of shelled corn were equally dissatisfied. This shows that custom and habit—something entirely extraneous to the food—are possible factors in palatability. Every practical stockman knows that to get the best results he must at all times provide feed for his animals which is palatable and altogether acceptable. This may be accomplished in considerable degree by steadily using the same feeds and feed combinations, and in always avoiding sudden and violent changes in their character and in the manner of feeding.

III. METABOLISM

We have learned how digestion prepares the various nutrients for the nourishment of the body. Let us now consider the manner in which the digested nutrients are brought from the alimentary tract into the body proper, and what becomes of them. Chemists and physiologists, working together with skill and great patience, have been able quite fully to explain the processes of digestion. When the nutrients leave the alimentary tract and enter the body, the difficulties of following them and learning what becomes of them are much greater. Many of the changes that occur in the body have been revealed by persevering scientists, but concerning others only little of a definite nature can yet be told.

Metabolism.—The processes by which the digested nutrients of the food are absorbed and used for the production of heat, work, and milk, or built up into the living matter of the body, in turn being broken down and once more becoming non-living matter, are termed *metabolism.*[2]

The circulatory canals of the body.—The body of the animal is made up of innumerable cells, which, grouped and modified in myriads of ways, form all its organs and parts. Everywhere among the cells are minute spaces called *lymph spaces,* which are connected with the lymphatics, a set of vessels which permeate most parts of the body. In some respects the lymphatics resemble the veins, but they are thinner and more transparent and drain in only one direction—toward the heart. Within these vessels is a clear fluid called *lymph.* These vessels unite with one another, forming a network in many places. Here and there a trunk subdivides into five or six smaller vessels, and the latter enter a nodule-like body called a *lymphatic gland.* From this gland come several small vessels, which, after a short space, again unite to form a trunk. Gradually these trunks unite, forming larger trunks until a large duct and another smaller one are formed which enter veins in the neck.

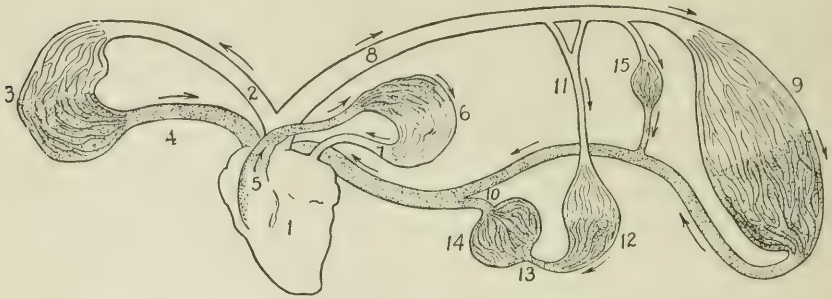

FIG. 10.—DIAGRAM OF THE CIRCULATION OF THE BLOOD

1, The heart; 2, artery carrying blood to the head and fore limbs; 3, circulation thru the upper portion of the body; 4, vein carrying blood from upper part of body back to the heart; 5, artery carrying venous blood to lungs; 6, circulation thru lungs; 7, vein carrying arterial blood back to heart; 8, artery carrying blood to lower portion of body; 9, circulation thru rear extremities; 10, vein carrying blood to heart from rear extremities; 11, artery carrying blood to intestines; 12, circulation thru intestinal capillaries; 13, portal vein carrying blood to liver; 14, circulation thru liver. (From Smith, "Manual of Veterinary Physiology.")

The arteries and the veins are the other set of canals. These permeate every portion of the body, the former carrying the blood away from the heart, and the latter carrying it to the heart. At the extremities of the arteries are still more minute tubes, called *capillaries,* which connect them with the veins. If one extends his arms in front of him with his finger tips touching, his body will represent the heart, while one arm will represent an artery carrying blood from the heart, and the other a vein conveying blood to the heart. The touching fingers will correspond to the capillaries connecting the arteries with the veins, and the space all about the fingers will represent the surrounding body tissues. In general, neither the veins nor the arteries allow any substance within them to escape thru their walls proper. It is thru the capillaries that the nutritive matter carried by the blood finds its way into the body tissues for their nourishment, and thru the capillaries and the lymphatics, in turn, the waste of the body drains back into the blood circulation.

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[2] Constructive metabolism, or the building-up processes, is termed anabolism, while the breaking-down and wasting processes are called catabolism.

The tissues of the body are thus everywhere permeated by the ducts of the lymphatic system and the capillaries of the blood system. The cells are bathed by lymph, which is the fluid that receives and temporarily holds all the nutritive substances and the body wastes.

The digested nutrients are absorbed into the circulation chiefly thru the walls of the small intestine. The mucous membrane lining it has a velvety appearance, caused by innumerable minute, cone-like projections, or tongues, called *villi,* which project into the interior of the intestinal tube, thereby coming into intimate contact with its fluid contents. Within each villus are *lacteals,* or drainage tubes of the lymphatic system, and capillaries of the blood system.

Digestion and absorption of fat.—In discussing the manner in which the various nutrients are absorbed, let us at the same time review their digestion, tracing just what becomes of each after entering the mouth.

The fats of food undergo no appreciable digestion until they reach the small intestine. Here thru the aid of the bile they are split by the lipase of the pancreatic juice into fatty acids and glycerin. The alkalies in the bile then unite with these fatty acids to form soaps. It is believed that practically all of the fats are absorbed in the form of soaps and glycerin; these are then reunited into fats in the intestinal wall. Some of the fatty acids and glycerin formed by the action of the lipase may perhaps be absorbed directly, without the fatty acids being first changed to soaps. In the villi of the intestinal wall the fats enter the lacteals, forming with the lymph a milky substance called *chyle.* This is carried by the lymphatics and poured into a vein near the shoulder, thus entering the blood circulation.

Digestion and absorption of carbohydrates.—Carbohydrate digestion begins in the mouth, where the ptyalin in the saliva changes starch into malt sugar. This action continues in the first part of the stomach, but ceases when the food becomes acid in the rear end of that organ. Simple, glucose-like sugars may be absorbed directly from the stomach in small amounts, but nearly all the carbohydrates are carried on into the small intestine. Here the starch which escaped being acted upon in the mouth or stomach is changed into malt sugar by amylase, an enzyme in the pancreatic juice. The compound cane, malt, and milk sugars are then split into simple glucose-like sugars by the action of the invertases, enzymes in the intestinal juice. These simple, glucose-like sugars, which are the only carbohydrates that can be used in the body, are absorbed thru the walls of the small intestine, and, entering the capillaries, pass into the veins and thence to the liver. Here they are for the most part withdrawn from the blood and temporarily stored in this organ as *glycogen,* a carbohydrate which is closely related to starch and, having the same percentage composition, is sometimes called animal starch. Normally from 1.5 to 4.0 per ct. of the weight of the liver consists of glycogen. The glycogen stored in the liver is gradually changed back into glucose, and then given out to the system as required, the amount of glucose in the blood being kept at about 1 part in 1,000. In addition to the liver, all the tissues of the body, especially the muscles, have some power to change glucose into glycogen.

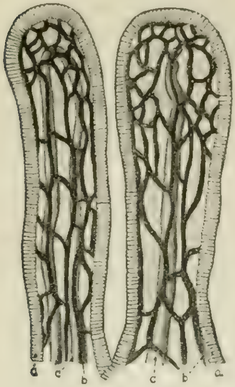

FIG. 11.—VILLI OF THE SMALL INTESTINE

A, Lining cells of intestine; b, net work of capillaries; c, lacteals. For the sake of simplicity the muscle fibers in the villi are not shown in this diagram. (After Cadiat.)

The cellulose and pentosans in the feed are attacked by bacteria in the first three stomachs of ruminants, in the caecum of horses, and to some extent in the large intestine of other animals. These bacteria break down the cellulose and pentosans into organic acids and also gases (marsh gas, carbon dioxid, and hydrogen), heat being produced in the process. The gases are of no value but the organic acids serve as food the same as sugars.

Digestion and absorption of protein.—The proteins of the food are first attacked in the stomach by pepsin, which splits them into proteoses and peptones. These are soluble and are simpler in composition than the proteins, but are still very complex in structure. The proteoses and peptones, together with protein which escapes action by pepsin, pass into the small intestine. There trypsin, an enzyme in the pancreatic juice, not only splits the undigested protein into proteoses and peptones, but also digests them further, splitting them into amino acids, which are much simpler than the proteoses and peptones. Erepsin, an enzyme in the intestinal juice, also acts on the proteoses and peptones and splits them into amino acids. Thus thru the action of the trypsin and erepsin all the protein which can be digested is split into amino acids. The amino acids are absorbed thru the walls of the small intestine and pass into the blood. They are then carried into the general circulation, and from the blood each of the parts of the body—muscles, organs, etc.—absorbs a certain amount to be used for repair or in growth.

A good picture of what takes place in protein digestion can be had by likening the food proteins to a house being taken down by a builder in order that he may construct another from the materials. An animal eating protein compounds cannot use them just as they are, but must first take them apart to a greater or less extent, and from the parts reconstruct other kinds of protein suitable for its own use. In other words, the proteins must have a different architecture from those in the plants. The proteoses and peptones may be likened to the roof and walls of the house. These walls and roof can be separated into bricks and tiles, which are represented by the amino acids; and from these the animal, beginning anew, can construct new proteins of the exact kind its body may require.

Mineral matter; water.—The mineral matter in feeding stuffs is not acted upon by any enzymes, but is dissolved in its passage thru the digestive tract, especially in the stomach by the acid in the gastric juice. It is absorbed chiefly from the small intestine.

Water requires no digestion and is absorbed chiefly from the small intestine, but also to some extent from the stomach and large intestine.

Distribution and use of absorbed nutrients.—We have seen that the digested fats which are to nourish the body are poured into the blood current by way of the lymphatics, while the glucose and the amino acids enter the blood directly thru the capillaries and veins. The veins from the small intestine unite and become the portal vein, which passes the blood thru the liver and on into the heart. The various nutrients, having been mingled with the blood, are carried thru the circulation to the capillaries.

These are so constructed that, when the blood finally reaches them, the nutrients it carries pass thru their walls and into the lymph that bathes the body cells. In this manner all the nutrients, having been especially prepared and transported, nourish every part of the body.

The nutrients may be oxidized, or burned, to warm the animal, or to produce energy to carry on the vital processes and to perform work, as shown in the following chapters. In case more nutrients are supplied than are required for these purposes, the excess may be built into body tissue proper, as shown in Chapter V. The glucoses may be converted into fats and stored as body fat, as may also the fats derived directly from the food fats. The amino acids may be built up into body protein or, if not needed for this purpose, a portion of their carbon, hydrogen, and oxygen may be changed into fat, while the nitrogen is excreted from the body. The highest use of the proteins, however, is the formation of nitrogenous tissues.

Disposal of waste.—As we have seen, the undigested food, together with some other waste material, is voided in the feces. Nearly all of the nitrogenous waste resulting from the breaking down of protein in the body is excreted in the urine thru the kidneys, tho a trace is given off in the sweat and some in the feces. In mammals this waste takes the form principally of urea. Some of the mineral matter, especially calcium, magnesium, and phosphorus, is excreted in the feces. The rest is voided in the urine.

In breaking up the food nutrients within the body for the production of heat and in the changes which occur in building them into body tissues, carbon dioxid is evolved. Most of this is absorbed from the stomach and intestines and is carried in the blood to the lungs, where it is passed out in breathing. Some of the marsh gas produced by fermentations in the stomach of herbivora is absorbed into the blood and thrown out by the lungs.

Summary.—In Chapter I we learned how the various inorganic compounds taken by plants from earth, air, and water are built into organic plant compounds, and how in such building the energy of the sun becomes latent or hidden. In this chapter we have learned how the animal, feeding on plants, separates the useful from the waste by mastication and digestion, and how the digested nutrients, after undergoing more or less change, are carried from the alimentary canal to the body tissues and used for building the body, for warming it, or in performing work. All the energy manifested by living animals and the heat produced in their bodies represent the energy of the sun originally stored in food substances by plants. With the breaking down of the nutrients in the bodies of animals, and in the decay of the animal substance itself, the organic matter loses the condition of life and falls back to the inorganic condition, once more becoming a part of the earth, air, and water. After this it is again gathered up by the plants and once more starts on the upward path. Such is the eternal round of Nature, in which plants, animals, the energy of the sun, and the mysterious guiding principle of life all play their parts.

QUESTIONS

1. State two fundamental differences in the composition of plants and animals.
2. How does the composition of an animal's body change as it grows? As it fattens?

3. Define digestion, digestible nutrient, ration, and balanced ration.
4. Describe the alimentary canal of the ox.
5. How does a cow chew her cud?
6. Define enzymes and describe the action of saliva on starch.
7. Describe digestion in (a) the mouth, (b) the simple stomach, (c) the stomach of ruminants, (d) the small intestine, (e) the large intestine.
8. What special provision has the horse for digesting roughages?
9. Define metabolism.
10. Describe the circulatory canals of the body.
11. Describe the digestion and absorption of (a) fat, (b) of carbohydrates, (c) of protein.
12. How is the body waste disposed of?

CHAPTER III

MEASURING THE USEFULNESS OF FEEDS

I. Digestibility of Feeds

In determining the relative usefulness of different feeding stuffs to the animal, it is necessary to find a means of measuring the amount of nutrients which each actually furnishes. The most simple method is to determine the digestibility of the various nutrients; i. e., the percentage of the total crude protein, fiber, nitrogen-free extract, and fat in the feed which is digested by the animal. The digestible matter is obviously the only portion of the feed which is of use, since the remainder passes out in the feces without ever having really entered the body.

A digestion trial.—In studying the digestibility of a given feed the chemist first determines by analysis the percentage of each nutrient it contains. The animal is then fed the feed to be tested for a preliminary period of a few days, in order that all residues of former feed may pass from the alimentary canal. Weighed quantities of the feed are then given to the animal and the feces voided during a stated period are collected and weighed, and samples are analyzed. The difference between the amount of each nutrient fed and that found in the feces resulting therefrom represents the digested portion.

To show the manner in which the digestibility of a feed is determined, let us suppose that during a 10-day trial a cow was fed 20 lbs. of clover hay each day, containing the amounts of nutrients shown in the table. During this time she excreted, on the average, 47.3 lbs. of feces, containing the amounts of undigested dry matter, crude protein, fiber, nitrogen-free extract, and fat shown in the table:

Digestion trial with cow fed clover hay; average for 1 day

	Dry matter	Crude protein	Carbohydrates		Fat
			Fiber	N-free extract	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Fed 20 lbs. hay, containing	17.4	2.6	5.1	7.7	0.62
Excreted 47.3 lbs. feces, containing	7.1	1.1	2.4	2.6	0.28
Digested	10.3	1.5	2.7	5.1	0.34
Per ct. digested	59.2	57.7	52.9	66.2	54.8

Subtracting the amounts of dry matter and of the different nutrients in the feces from the amounts in the feed, we find the amounts digested. From this we compute the percentage of each which is digested. For example, there was 17.4 lbs. of dry matter in the 20 lbs. of hay the cow ate each day. Of this, 7.1 lbs. was excreted in the feces, leaving 10.3 lbs., or 59.2 per ct., as the part digested.

Some feeds cannot be fed alone, as was done in this trial. For instance, horses and ruminants are not fed concentrates alone without hay or other roughage. Again, while pigs may be fed on grain only, such feeds as tankage and linseed meal are too rich in protein to be so fed. The digestibility of such feeds must, therefore, be found by difference, instead of directly. To illustrate, a horse is first fed hay for several days and the digestibility of the hay determined. Oats may then be added to the ration, and the total amounts of nutrients digested from both feeds are found, just as in the preceding method. The amount of digestible nutrients coming from the hay is then subtracted from the total, leaving the amount assumed to be digested from the oats.

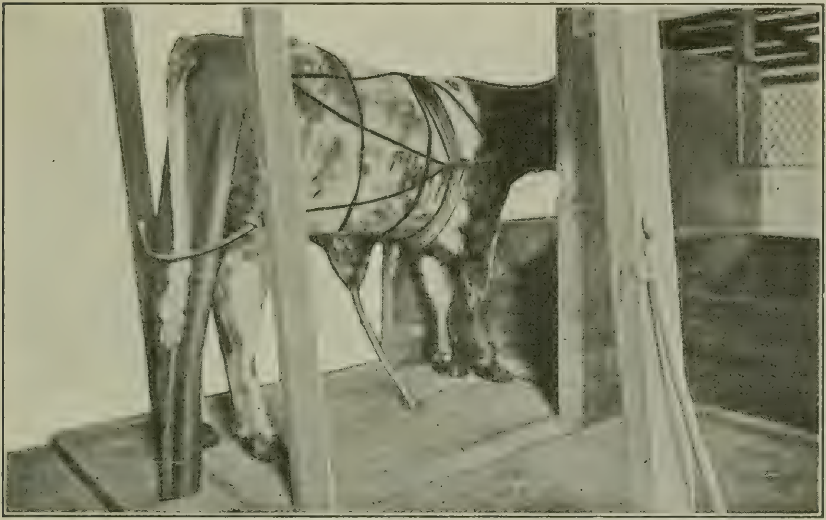

FIG. 12.—A STEER IN A DIGESTION STALL

In digestion trials the feces may be collected in several ways. A common manner is by means of the harness and rubber duct here shown. When it is merely desired to determine the digestibility of a feed, the urine need not be collected. In other nutrition studies the urine must be collected, as is being done in this trial. (From Armsby, Penn. Sta.)

Digestion coefficients.—The average percentage of each nutrient digested in a feeding stuff is termed the *digestion coefficient,* or *coefficient of digestibility,* for that nutrient in the feed. In Appendix Table II are given the digestion coefficients for some of the leading American feeds, selected from the extensive table in the unabridged edition of "Feeds and Feeding." This table shows that feeds which contain little fiber, such as corn and wheat, are highly digestible, because the cell walls are thin and easily penetrated by the digestive juices. The higher the fiber content of feeds, the thicker and more resistant are the cell walls, and consequently the less digestible are the feeds, as a rule. Thus, oats and wheat bran are less digestible than corn or wheat, and the roughages, such as hay and straw, have still lower digestion coefficients. In general, the nitrogen-free extract of feeds is slightly more digestible than the crude protein or fat, and much more digestible than the fiber.[1]

Digestible nutrients in feeding stuffs.—To find the digestible nutrients in any feeding stuff the total amount of each nutrient in 100 lbs. of it is multiplied by the digestion coefficient for that nutrient. For example, 100 lbs. of dent corn contains 10.1 lbs. of crude protein (See Appendix Table I), of which 74 per ct. is digestible, as shown in Appendix Table II. Accordingly, there are 10.1 × 0.74 or 7.5 lbs. of digestible protein in 100 lbs. of dent corn. In this manner the authors have computed the data in Appendix Table III, which show the digestible nutrients in the important American feeding stuffs. (This table is condensed from the exhaustive and complete table in the unabridged edition of "Feeds and Feeding.") For purposes of illustration, the following examples are presented on the next page.

In Appendix Tables I and II the fiber and nitrogen-free extract are given in separate columns, for, tho of the same chemical composition, these components often differ widely in digestibility. In preparing tables of digestible nutrients, the digestible fiber and digestible nitrogen-free extract are determined separately and the results combined

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[1] In digestion trials it is commonly assumed that all matter appearing in the feces represents the part of the food which is actually indigestible. This is only approximately correct, for the feces always contain some waste from the body itself, such as bile residues, matter coming from the walls of the alimentary canal, and unabsorbed digestive juices. Also, as we have seen in the preceding chapter, thru the action of bacteria in the paunch and large intestine, some of the nutrients, especially the fiber, are broken down into gas, which has no nutritive value. Yet this is usually included in the amount considered to be digestible. Furthermore, in digestion studies the ether extract, or so-called fat, is extracted by ether, which dissolves not only the true fat, but also the chlorophyll, wax, bile residues, and other substances which are not true fat. Due to this, and because the fats in feeding stuffs are usually in relatively small amount errors are liable to occur in finding their digestibility.

Digestible nutrients in 100 lbs. of typical feeding stuffs, from Appendix Table III

Feeding stuff	Total dry matter	Digestible nutrients				Nutritive ratio
		Crude protein	Carbohydrates	Fat	Total (inc. fat x 2.25)	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
Concentrates—						
Dent corn	89.5	7.5	67.8	4.6	85.7	1:10.4
Oats	90.8	9.7	52.1	3.8	70.4	1: 6.3
Wheat	89.8	9.2	67.5	1.5	80.1	1: 7.7
Wheat bran	89.9	12.5	41.6	3.0	60.9	1: 3.9
Linseed meal, old process	90.9	30.2	32.6	6.7	77.9	1: 1.6
Roughages—						
Timothy hay	88.4	3.0	42.8	1.2	48.5	1:15.2
Red clover hay	87.1	7.6	39.3	1.8	51.0	1: 5.7
Oat straw	88.5	1.0	42.6	0.9	45.6	1:44.6
Kentucky bluegrass, green	31.6	2.3	14.8	0.6	18.5	1: 7.0
Corn silage	26.3	1.1	15.0	0.7	17.7	1:15.1
Mangels	9.4	1.0	6.1	0.1	7.3	1: 6.3

under the term *carbohydrates*, as is done in this table. The digestible carbohydrates in dent corn are computed as follows: According to Appendix Table I, 100 lbs. of dent corn contains 2.0 lbs. of fiber, 57 per ct. of which is digestible, as shown in Appendix Table II. Likewise there are 70.9 lbs. of nitrogen-free extract, 94 per ct. of which is digestible. Multiplying in each case and adding the products, we have 67.8 lbs., the amount of digestible carbohydrates in 100 lbs. of corn.

To show the entire amount of digestible nutrients in 100 lbs. of each feed, the fifth column gives the sum of the digestible crude protein and carbohydrates, plus the fat multiplied by 2.25, because fat will produce 2.25 times as much heat in the body as carbohydrates or protein.

The table shows the wide differences in the amounts of digestible nutrients these typical feeds furnish. Corn and wheat are high in digestible carbohydrates and rather low in digestible protein, while wheat bran and linseed meal are high in digestible protein but low in digestible carbohydrates. The roughages range lower in digestible nutrients than the concentrates. Oat straw is especially low in digestible protein, while immature and actively growing pasture grass will contain nearly as much digestible protein as wheat bran, if cut and dried to the same water content.

Nutritive ratio.—As protein serves special uses in the body, in discussions of feeding stuffs and rations the term nutritive ratio is used to show the proportion of digestible protein they contain. By *nutritive ratio* is meant the ratio which exists in any given feeding stuff between the digestible crude protein and the combined digestible carbohydrates and fat. It is determined in the following manner: The digestible fat in 100 lbs. of the given feed is multiplied by 2.25, because fat will produce 2.25 times as much heat on being burned in the body as do the carbohydrates. The product is then added to the digestible carbohydrates and the sum is divided by the amount of digestible crude protein, the quotient being the second term of the ratio. The manner of computing the nutritive ratio of dent corn is as follows:

$$\frac{\overset{\text{Diges. fat}}{(4.6} \times \overset{\text{Heat equiv.}}{2.25)} + \overset{\text{Diges. carbohy.}}{67.8}}{\underset{\text{Diges. crude protein}}{7.5}} = \overset{\substack{\text{Second term of}\\ \text{nutritive ratio}}}{10.4}$$

Nutritive ratios are expressed with the colon, thus, 1:10.4. The nutritive ratio of dent corn is therefore 1:10.4 (read 1 to 10.4); i. e., for each pound of digestible crude protein in corn there are 10.4 lbs. of digestible carbohydrates or fat equivalent. A feed or ration having much crude protein in proportion to carbohydrates and fat combined is said to have a *narrow nutritive ratio;* if the reverse, it has a *wide nutritive ratio.* Oat straw has the extremely wide nutritive ratio of 1:44.6, because of its low content of digestible protein compared with the carbohydrates and fat; oats the medium one of 1:6.3; and protein-rich linseed meal the very narrow ratio of 1:1.6, the carbohydrates being less than twice the crude protein.

When the total digestible nutrients (including fat × 2.25) in a feed or ration are given, as in Appendix Table III and the preceding table, the nutritive ratio may be computed by simply subtracting the digestible crude protein from the total digestible nutrients, and dividing the remainder by the digestible crude protein. For example, the nutritive ratio of dent corn is found thus: $(85.7 - 7.5) \div 7.5 = 10.4$, second term of nutritive ratio.

The term *carbonaceous feed* is a convenient designation for a feeding stuff having a wide nutritive ratio. Similarly, the term *nitrogenous feed* designates a feeding stuff having a narrow nutritive ratio.

II. The Energy of Food

Tables of digestible nutrients tell what part of the food may be digested and absorbed, and thus really enter the body of the animal, but they throw no light on the use made of the nutrients when once they are within the body. To obtain such information the *respiration apparatus* and the *respiration calorimeter* have been devised.

The respiration apparatus.—This is an air-tight chamber, arranged with such devices that all that enters and comes from the body of the animal placed within it can be accurately measured and studied. In some cases mechanical work is performed, while in others the animal is at rest. Everything which passes into the animal—air, food, and water—is carefully measured and analyzed so that the exact intake of the body is known. The air is in turn drawn from the chamber and analyzed, and the feces and urine passed by the animal are likewise weighed and analyzed. If the intake is larger than the outgo, the animal has increased in body substance; if less, it has lost. For example, if the feed given a steer during 24 hours contains 0.75 lb. of nitrogen and the feces and urine voided during the same day contain 0.64 lb., the steer has stored 0.11 lb. of nitrogen in its body during the day in the form of protein tissue. Similarly, if the feed contains

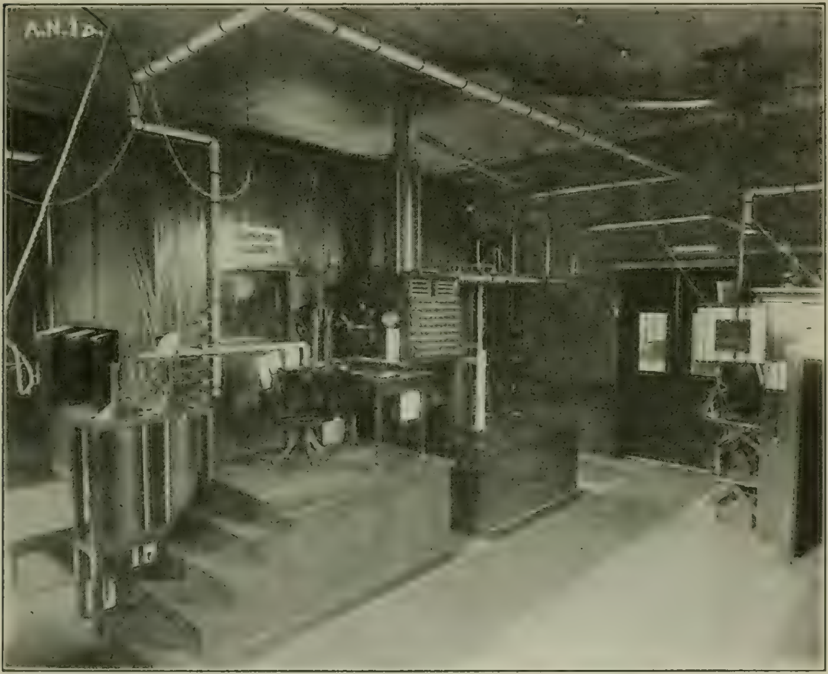

FIG. 13.—THE RESPIRATION CALORIMETER AT THE PENNSYLVANIA STATION

Calorimeter chamber in the corner of the room at the left. Thru the use of this apparatus much light has been thrown on the value of different classes of feeds. (From Armsby, Pennsylvania Institute of Animal Nutrition.)

13 lbs. of carbon and the steer voids 12.25 lbs. during the day in the feces and urine, and in the carbon dioxid in the air breathed out of the lungs, then 0.75 lb. of carbon must have been stored in his body. Some of this will be in the protein tissues built during the day, while the remainder will have been stored as fat. Thru such trials scientists have been able, in some measure, to tell what becomes of the food animals consume.

The respiration calorimeter.—A still more accurate means of measuring the usefulness of feeds is furnished by the *respiration calorimeter.* This is an improved and exceedingly complicated form of the respiration apparatus, in which not only the feces, urine, and gaseous waste products can be collected, but in which the heat given off by the animal can also be accurately measured. By means of this apparatus, it is possible to find exactly how much of the energy or fuel value of the feed the animal has been able to use in growth, fattening, or work. The first and only respiration calorimeter built in this country for carrying on experiments with large animals was erected by Armsby at the Pennsylvania Station some years ago.

Fuel value of feeds.—A mature animal may be compared to a steam engine, in which a part of the power derived from the fuel is used for the operation of the engine itself, while the surplus may perform useful work. The steam engine derives its energy from coal or wood; the animal, from the feed it consumes. Both require a small amount of repair material—steel, brass, etc., for the engine, and protein and mineral matter for the animal—but the largest demand with engine and mature animal alike is for fuel. It is therefore both important and interesting to consider the relative value of feeds in terms of the fuel they can furnish the body.

The value of any feeding stuff as fuel for the animal depends on the amount of energy which it will furnish when burned. As with coal, the fuel value of a feed is determined by burning a weighed quantity of it in pure oxygen gas under pressure in an apparatus called a *calorimeter.* The heat given off is taken up by water surrounding the burning chamber and is measured with a thermometer, the units of measure employed being the Calorie and the therm.

A *Calorie* (C.) is the amount of heat required to raise the temperature of 1 kilogram of water 1° C., or 1 lb. of water nearly 4° F. A *therm* (T.) is 1,000 Calories.

The fuel value of 100 lbs. of various substances, or the heat evolved on burning them, is as follows:

	Therms
Anthracite coal	358.3
Timothy hay, containing 15 per ct. moisture	179.3
Oat straw, containing 15 per ct. moisture	171.0
Corn meal, containing 15 per ct. moisture	170.9
Linseed meal, containing 15 per ct. moisture	196.7
Pure digestible protein	263.1
Pure digestible carbohydrates	186.0
Pure digestible fat	422.0

The table shows that, on burning, 100 lbs. of anthracite coal yields 358.3 therms, or enough heat to raise the temperature of 358,300 lbs. of water 4° F. One hundred pounds of timothy hay likewise burned yields 175.1 therms, or about half as much as coal. Linseed meal has a higher fuel value than corn meal because it contains more oil. Digestible protein yields considerably more heat than the carbohydrates, and fat over twice as much as the carbohydrates.

Available energy.—The fuel value of any feed does not necessarily measure its nutritive value to the animal, because feeds which yield the same number of heat units in the calorimeter may vary in the amount of available energy which they can furnish to the body. This is because:

1. A part of the food consumed passes thru the alimentary tract undigested. This may be compared to bits of coal dropping thru the grate of the boiler unburned.

2. The carbohydrates, especially woody fiber, undergo fermentations in the intestines and paunch, combustible gases, especially methane or marsh gas, being formed, which are without fuel value to the animal. Even in well-constructed engines a similar loss of energy occurs in the combustible gases which escape thru the chimney without being burned.

3. When the protein substances in the body are broken down they form urea, a nitrogenous compound which is excreted by the kidneys. Urea has fuel value which is lost to the body. Again we may liken this loss to that which occurs in the boiler thru the creosote which, tho having fuel value, is not burned in the fire box but escapes or is deposited in the chimney.

The fuel value of any food which remains after deducting these three losses represents the *available energy* of the food. This is the portion which the animal can use for body purposes.

Net energy.—The available energy of the food measures its value for heat production in the animal, but does not represent its true value for other purposes. The animal must spend a part of the total available energy of any food in the work of masticating and digesting it and assimilating the digested nutrients. The energy so expended finally takes the form of heat, but is wasted so far as other uses are concerned. That portion of the energy which remains after masticating, digesting. and assimilating the food is termed the *net energy* of the food. This net energy is used by the animal, first of all, in the work of the heart, lungs, and other internal organs, and in case a surplus of net energy then remains, such surplus may be used for producing growth, fat, milk, or wool, or in the performance of external work.

The losses of energy due to mastication, digestion, and assimilation may be compared to the losses which would occur if a gasoline engine had to distil its own gasoline from crude petroleum and then get rid of the impurities which it could not use.

Net energy of feeding stuffs.—Our knowledge of the net energy value of different feeds has been obtained largely thru the painstaking experiments conducted by Kellner in Germany and Armsby in this country. The following table sets forth some of their findings with reference to what becomes of the digestible nutrients and three common feeding stuffs when fed to the ox:

Net energy from 100 lbs. of digestible nutrients and common feeding stuffs

Nutrients or feeding stuffs	Total energy	Energy lost					Net energy remaining
		In feces	In methane gas	In urine	In production processes	Total loss	
	Therms	Therms	Therms	Therms	Therms	Therms	Therms
Digestible nutrients							
Peanut oil (fat)	399.2	0.0	0.0	0.0	174.4	174.4	224.8
Wheat gluten (protein)..	263.1	0.0	0.0	49.2	118.3	167.5	95.6
Starch (carbohydrate) ..	186.0	0.0	18.8	0.0	68.7	87.5	98.5
Common feeding stuffs							
Corn meal	170.9	15.7	15.9	6.6	62.0	100.2	70.7
Timothy hay	179.3	87.7	6.8	5.5	52.9	152.9	26.4
Wheat straw	171.4	93.9	15.5	4.3	47.4	161.1	10.3

The first column of the table shows the total amount of energy which would be produced on burning 100 lbs. of the digestible nutrients or of typical feeding stuffs. With the digestible nutrients no further loss occurs in the feces, but all are absorbed out of the small intestine and go into the body proper. The oil contained no nitrogen, and so no nitrogenous waste from it appeared in the urine, nor did any of it form methane (marsh) gas in the intestines. To digest and assimilate this 100 lbs. of oil required 174.4 therms of energy, leaving 224.8 therms as the net energy value for growth, fattening, work, or milk production.

When 100 lbs. or 263.1 therms of wheat gluten, which is principally protein, was digested and absorbed into the body, a loss of 49.2 therms occurred in the urine, this loss coming from the breaking down of this protein nutrient within the body, or from the breaking down of body tissue which was replaced by new protein from this source. In all 167.5 out of 263.1 therms in 100 lbs. of gluten were lost either in the urine or in carrying on the work of mastication, digestion, and assimilation, leaving 95.6 therms which might be temporarily or permanently stored in the body. This amount of protein was available for building protein tissues or lean meat, which would be its highest use, or it could serve for the production of body fat, etc.

Studying the data for the feeding stuffs, we observe that 100 lbs. of corn meal contains 170.9 therms of total energy. Of this, 15.7 therms is lost in the undigested matter of the feces. In the methane gas formed in the fermentations in the paunch there was a loss of 15.9 therms. A further loss of 6.6 therms occurred in the urine. Adding these losses together and subtracting the sum from the total energy value, 170.9 therms, we find that 132.7 therms remained. This is the amount of *available energy* in 100 lbs. of corn meal. Further losses of energy, amounting to 62.0 therms, take place thru the production processes; i. e., masticating the corn, digesting it and assimilating the digested nutrients. This brings the total loss to 100.2 therms, leaving 70.7 therms as the *net energy* value of the 100 lbs. of corn meal. The same weight of timothy hay furnishes but 26.4 therms of net energy and of wheat straw but 10.3 therms. About one-half of the total fuel value of these feeds passes off as undigested matter, never having been inside the body proper.

Such roughages as straw, hay, and corn stover, because of their coarse, woody character due to the fiber they contain, place much work on the animal in digesting them and passing the waste out of the body. This means an evolution of heat. Therefore where the animal, such as an idle horse in winter, is doing no work and needs little net energy, no harm but rather economy in cost of keep may result from living on such roughages, because the large amount of heat necessarily produced in the digestion and assimilation of this food helps keep the animal warm. On the other hand, animals at hard work and those producing milk or being fattened cannot profitably live chiefly on coarse forage but must have liberal allowances of concentrates, such as corn or oats, for they need large amounts of net energy in their rations.

Due to the immense amount of work required in each individual trial, the net energy values have as yet been determined for only a small number of feeds. Thus, as we shall see in Chapter VIII, our present knowledge of the net energy value of feeds is far from complete. However, tho many of the values are not exact and final, they are of great value in showing approximately what portions of the food consumed by animals are lost at each step in its progress thru the body, and what part is finally available for growth, fattening, work, or milk production. The marvel is that scientists have been able to go so far in solving these most complicated problems.

III. Factors Influencing the Nutritive Value of Feeds

Variations in composition of feeding stuffs.—The figures given in Appendix Table I for the composition of any feed are in most instances averages of all analyses of normal samples of that feed which have been reported by the various stations. It is obviously important to learn what variations from these averages may be expected in the case of samples of a given feed from different sections of the country, grown in different years, or when gathered at different stages of maturity. The composition of a crop may be influenced to a limited extent by the amount of available plant food in the soil on which the crop is grown. Climate and stage of maturity are, however, the most important factors affecting the composition of a given feed. Of the cereals, wheat is the most variable in composition, its protein content being profoundly influenced by climate. While the average crude protein content of wheat from the northern plains states is 13.5 per ct., wheat from the Atlantic states contains only 11.7 per ct. and that from the Pacific states but 9.9 per ct. crude protein. Climate has little effect on the chemical composition of corn, providing the crop matures.

The roughages are even more variable in composition than the cereals, owing to the fact that, besides climate, their composition is influenced by the stage of maturity, the manner of curing, and the moisture content. Analyses of corn fodder and corn stover show a water content ranging from over 50 per ct. in field-cured material in wet seasons down to 10 per ct. or less in arid regions or where cured under cover in a dry season. To show the difference in nutritive value of these extremes it may be stated that corn fodder or stover containing 10 per ct. water will carry 80 per ct. more nutrients per 100 lbs. than a sample of the same forage containing 50 per ct. water! To overcome this error so far as possible, separate averages are given for very dry and for ordinary field-cured samples of these feeds in Appendix Table I.

When plants are immature a much larger percentage of the dry matter consists of protein than when they are mature. For example, dried alfalfa from plants cut when three inches high may contain over

30 per ct. crude protein, while the dry hay from alfalfa cut when in bloom will contain only half as much. On the other hand, immature plants are more watery, and thus contain less total digestible nutrients.

It is shown in later chapters that as the grasses and legumes mature their content of fiber materially increases, and as a consequence the feed becomes less digestible and usually of lower value. However, the large accumulation of starch which occurs in the corn plant as it ripens gives the more mature form of that plant a greater total feeding value.

Influence of preparation of feed.—It is often assumed that by cutting, grinding, and cooking feed much labor is saved the animal, to the advantage of the feeder. This idea is based on the theory that the less work the animal does in mastication and digestion the larger the net production of work, flesh, or milk. On the contrary, we know that the muscles of the body do not grow strong thru idleness, and that work and activity are necessary to bodily health, growth, and strength. Likewise, the organs of mastication and digestion should be kept working at their normal capacity. When cutting, grinding, cooking, or pulping brings more satisfaction to fattening animals soon to be slaughtered, and causes them to consume heavier rations, such preparation may pay, as it may also with exceptionally hard-worked animals that have but limited time for taking their rations. Ordinarily, making feeds fine and soft so they may be swallowed with little chewing not only fails to pay for the cost of such preparation but may actually lower the value of the feed. The economy of the different methods of preparing feed for each class of stock is discussed in detail in the respective chapters of Part III, but a summary of these conclusions will be helpful in showing the principles which should govern the feeder in deciding how far to employ such methods of preparation.

Grinding or crushing grain.—Grinding, crushing, or rolling grain increases the digestibility only when animals fail to masticate the whole grain. In fact, grinding grain so finely that it is bolted with little chewing may sometimes decrease the digestibility because of imperfect mixture with the saliva. For all animals, such hard grains as bald barley or rice should be ground, and for all classes of animals, except perhaps sheep, small seeds, such as millet, grain from the sorghums, or weed seeds, should ordinarily be ground. For animals with poor teeth or for young animals before their teeth are well developed, grinding grain in general is advisable. Ordinarily, horses can grind their own oats and corn, and idle horses should always do so. For horses which are hard-worked and spend much of their time away from the stable the grain may be ground and mixed with a small allowance of moistened chaffed hay. A cow yielding a large flow of milk is a hard-worked animal, and her grain should usually be ground. Where pigs follow fattening cattle to gather up any grain which escapes mastication and digestion there is no advantage in grinding corn or even shelling it, except perhaps toward the close of the feeding period when the cattle may be induced to eat more by grinding. Where no pigs run with cattle, it is usually economical to grind or crush the corn before feeding. Except in the case of small or hard seeds, sheep with good teeth should grind their own grain. While it pays to grind the small grains for pigs, there is no appreciable advantage in grinding corn for pigs weighing 150 lbs. or less. For older animals such preparation may sometimes be profitable.

Cutting or chaffing forage.—Passing such coarse forages as corn or the sorghums thru a feed cutter or shredder is usually profitable, not because the portions consumed are digested more completely but because the animals waste less of the feed and the cut forage is more convenient to handle. Whether it will pay to cut or grind hay will depend on the price, on the quality of the hay, and the cost of preparation. When hay is cheap, there is little gain in thus preparing good hay which will otherwise be eaten with little waste, tho it may pay to cut poor hay so that it will be eaten more completely. With hay at present prices, it is becoming more profitable to cut hay for stock. Hay may be cut sufficiently fine for most purposes at low cost on the farm by means of a silage cutter equipped with an alfalfa screen. Cutting alfalfa hay is now practiced by many extensive feeders in the western states, especially for fattening steers and lambs. The value of alfalfa meal is discussed on Page 184.

Soaking feed.—When grain with hard or small kernels can not be conveniently ground or crushed, it should be softened by soaking before feeding, care being taken that the meal does not become stale by long standing.

Cooking feed.—Only 60 years ago scientists believed that cooking feed greatly increased its value for stock. Numerous careful trials have since shown that, in general, cooking either grain or roughage does not increase its digestibility or nutritive value, and may even decrease the digestibility of the protein. While cooking feed for cattle was abandoned years ago, it is still practiced to some extent for swine. Fortunately, this question has also been settled by numerous tests at several experiment stations. These showed conclusively that, rather than there being a gain, there was in most cases an actual loss from cooking. The only exceptions are a few feeds, such as potatoes and field beans, which can be successfully fed to pigs only after being cooked. When such small and hard grains as wheat and rice can not be ground they should be cooked or soaked. Musty hay and corn fodder are made more palatable and safe by steaming. In winter it is often advantageous to give warm feed to pigs, but this is entirely different from cooking the feed.

Curing and ensiling forage.—If green forage is cured without waste and in a manner to prevent fermentation, the mere drying does not lower its digestibility. Ordinarily, however, in curing forage much of the finer and more nutritious parts is wasted, and dews, rain, and fermentations effect changes which lower digestibility. The large amount of work done in masticating dry forage and passing it thru the alimentary tract is another reason why green forage may give better results and hence appear more digestible than dry forage. The long storage of fodders, even under favorable conditions, decreases both their digestibility and palatability.

Ensiling green forage tends to decrease the digestibility. The exceedingly favorable results from silage feeding must therefore be due to the palatability of the silage, its beneficial effect on the health of the animals, and to the fact that less feed is wasted than when dry fodder is used.

Influence of amount of feed eaten on digestibility.—Animals tend to digest their food somewhat more completely when given a maintenance ration than when on full feed. This may be due to the more rapid movement of the food thru the digestive tract or to a less complete absorption of the digested nutrients when present in large amount. Under normal conditions, in feeding farm animals for the production of meat, milk, or work, other economic factors, which will be treated in later chapters, more than offset the slightly better utilization of feed when a scant ration is fed.

Influence of proportion of the different nutrients.—The addition of a large quantity of easily digested carbohydrates, such as sugar and starch, to a ration containing much roughage may reduce the digestibility of its crude protein, fiber, and nitrogen-free extract. Such *depression of digestibility* occurs with ruminants when less than 1 part of digestible crude protein is present to every 8 parts of digestible non-nitrogenous nutrients (carbohydrates plus fat × 2.25). With swine the nutritive ratio may be wider before the digestibility is affected. An explanation offered for this lessened digestibility is that when a large proportion of soluble or easily digested carbohydrates is fed, the bacteria in the digestive tract which normally decompose cellulose to secure food then attack instead the more readily available sugars and starch. Not only is the digestibility of the cellulose, or fiber, consequently lowered, but also that of the crude protein and nitrogen-free extract, for the unattacked cellulose cell walls protect the proteins and carbohydrates contained therein from the action of the digestive juices. This depression does not occur when nitrogenous feeds, such as oil meal, are added along with the starch or sugar, thus preserving the balance between protein and non-nitrogenous nutrients. It is assumed that this is due to a stimulation of the bacteria by the addition of more protein, so that, invigorated, they attack the fiber of the food again.

Adding nitrogenous feeds to roughages, such as hay, straw, etc., does not increase the digestibility of the roughage. Neither does the addition of fat to a ration increase the digestibility of the other constituents. When too much fat is fed it may cause digestive disturbance. Salt does not affect digestion, tho it may cause animals to eat more food and may improve nutrition.

Class of animal, age, breed, and miscellaneous factors.—Cattle and sheep digest concentrates and good quality roughage equally well, but cattle digest poor roughage, such as straw, somewhat better than sheep. Horses and pigs digest fiber less completely than do ruminants. While there is little difference in the digestibility of concentrates by these animals, horses cannot digest roughages as completely as do cattle or sheep, and pigs utilize roughages still less efficiently.

In general, age does not, in itself, influence digestibility, tho young farm animals cannot utilize much roughage until their digestive tracts are developed. The digestion of old animals is often indirectly injured by poor teeth, which make the proper mastication of their food impossible. Breed has no influence upon digestibility. Animals may, however, show considerable difference, one from another, in their ability to digest the same ration, tho ordinarily the digestibility of a given ration by different animals of the same race will not vary more than 3 to 4 per ct.

Neither the frequency of feeding, the time of watering, nor the amount of water drunk appears to influence digestibility. Moderate exercise tends to increase digestibility, but excessive work lowers it.

The flow of saliva and the other digestive juices is checked by fright. On the other hand, kind treatment and palatability of food should favorably influence digestion. Under skillful care animals show remarkable relish for their food, and it is reasonable to conclude that better digestion results.

Summary.—The preceding discussions make it evident that average figures for the composition of any feeding stuff are but approximately correct when applied to a particular lot of the feed. This likewise applies to the expression of its nutritive value, whether stated in terms of digestible nutrients or net energy. In other words, different lots of any feeding stuff vary in feeding value, the same as different samples of coal vary in fuel value. Owing to the expense of obtaining analyses it is out of the question for any but the most extensive feeders to have their particular feeds analyzed, just as only the large manufacturer can afford to have samples of coal analyzed to determine their fuel value before purchasing. With the cereals and the roughages the general feeder must, therefore, rely on that average given in tables of digestible nutrients or net energy which corresponds most closely in his judgment to the feed at hand. In purchasing commercial concentrates, sold in vast quantities everywhere, it is now fortunately possible in most sections of the country to secure standard brands, whose composition is fully guaranteed by the manufacturer. (Chapter XI.)

QUESTIONS

1. What are digestion coefficients and how are they found in a digestion trial?
2. In a digestion trial a steer ate in one day 25 lbs. of red clover hay containing 86.4 per ct. dry matter, 12.5 per ct. crude protein, 25.2 per ct. fiber, 38.3 per ct. nitrogen-free extract, and 3.3 per ct. fat. During the same day he voided in the feces 8.9 lbs. dry matter, 1.3 lbs crude protein, 2.9 lbs. fiber, 3.3 lbs. nitrogen-free extract, and 0.4 lb. fat. Find the digestion coefficients for dry matter and the various nutrients.
3. Define nutritive ratio and show how it is calculated.
4. Describe a respiration apparatus.
5. Define available energy and net energy.
6. Thru what different means is energy lost when a cow eats corn meal?
7. Why may considerable straw be fed advantageously to an idle horse but not to one at hard work?
8. What factors influence the composition of feeds?
9. Discuss the value for stock of (a) grinding grain, (b) cutting hay, (c) soaking feed, (d) cooking feed.
10. How is the value of forage affected by curing; by ensiling?
11. What factors affect the digestibility of feeds?

CHAPTER IV

MAINTAINING FARM ANIMALS

I. Requirements for Body Fuel

Farm animals are given food in order that they may convert it into useful products, like meat, milk, wool, and work. Just as a factory must be supplied with power to keep the machinery in motion before any product can be turned out, to make continued production possible with the animal enough food must first be provided to maintain all necessary life processes. This amount of food, which is required merely to support the animal when doing no work and yielding no material product, is called the *maintenance ration.* When an animal is receiving a maintenance ration its body will neither gain nor lose protein, fat, or mineral matter. On the average, fully one-half of the feed consumed by farm animals is used simply for maintenance, only the remaining half being turned into useful products. Thus it is highly important to understand the principles governing the maintenance requirements of farm animals.

To maintain an animal at rest without losing or gaining in weight, sufficient food must be supplied to furnish: (1) Fuel to maintain the body temperature; (2) energy to carry on such vital functions as the work of the heart, lungs, etc.; (3) protein to repair the small daily waste of nitrogenous tissues; (4) mineral matter to replace the small but continuous loss of these nutrients; (5) vitamines, recently discovered, mysterious substances which are necessary for health.

Maintaining the body temperature.—The body temperature of the larger farm animals ranges from 98.4° to 105.8° F. To keep the body at these high temperatures, heat must be continuously produced within it. We have seen that, especially with ruminants, much heat is generated in the digestive tract by the breaking down of cellulose and other plant compounds. The remainder is produced in the tissues of the body in the following manner: Thru breathing, the oxygen of the air is brought to the blood. Floating in the blood stream, are myriads of microscopic bodies called red blood corpuscles, which owe their color to hemoglobin, an iron-containing protein. This hemoglobin absorbs the oxygen and holds it loosely. As the blood, now laden with oxygen, passes thru the capillary system, it gives up the oxygen to the living body cells. Here, in some marvellous manner some of the body nutrients are oxidized, or slowly burned, with the result that heat is formed. Unlike the burning of fuel in a stove, the oxidations in the body take place at a comparatively low temperature. As a result of these oxidations, where there were before glucose, fats, and proteins in the tissues, there now remain carbonic acid gas, water, and urea. The latter is the form in which the nitrogenous waste of the body, resulting from the breaking down of protein is chiefly excreted.

As shown in the preceding chapter, all the energy used up in the various forms of internal work of the body is finally changed to heat. Tho this energy is lost so far as useful production is concerned, the heat formed helps to maintain the body temperature. The amount of heat so produced is considerable. Even with such an easily digested feed as corn, over one-third of the total energy which the digestible nutrients furnish is converted into heat in the work of masticating, digesting, and utilizing it. With roughages like hay and straw the proportion is much larger. However, in the case of animals exercising normally the larger part of the body heat is produced in the muscular tissues, since all muscular contraction is caused by the oxidation, or burning, of nutrients in the muscles. Even when the muscles are not actively contracting, some heat is being generated in them.

Heat regulation.—Not only must heat be continuously produced in the body, but the temperature must be kept constant under varying external conditions and with supplies of food differing from day to day in amount and heat producing power. This is done by the unconscious regulation of both the production and the loss of heat. The production of heat is governed by decreasing or increasing the oxidations going on in the body tissues. On cold days, for example, we are inclined to eat more heartily and walk more briskly than in warm weather. When chilled, there is also an involuntary rise in heat production, brought about thru a ''shivering'' of the muscles. The loss of heat from the body is regulated in part by varying the circulation of the blood near the surface of the body. When the temperature of the body is too high, more blood is pumped to the surface, where some of the heat passes off into the air. The production of sweat and the giving off of water vapor from the lungs are also important means of governing the loss of heat. In addition, the clothing of man and the thick skin, hair, wool, and feathers of animals prevent too rapid loss of heat.

Heat and energy required for maintenance.—In maintaining a mature animal at rest a certain amount of net energy must be furnished by the feed to carry on the internal work of the body. However, the greater part of the food is required merely as fuel to keep up the body temperature. Hence, except for the pig, maintenance rations for the larger farm animals may consist largely of cheap roughages, such as hay and straw, which furnish abundant heat but do not yield much net energy. This has great practical importance, for it shows why idle horses and stock cattle can be carried thru the winter on roughage alone, without grain.

It is commonly assumed in computing rations that the amount of feed required to maintain an animal depends on its body weight. Strictly speaking, however, the maintenance requirement depends not on the live weight, but on the body surface. This is due to the fact that the loss of heat from the body is proportional to the body surface and not to its weight. A 1,600-lb. steer does not have twice the body surface of an 800-lb. one, and hence will not require twice as much feed for maintenance. Individual animals of the same kind and size may also differ somewhat in their requirements. For example, a quiet animal uses up less body fuel than a nervous, active one. Due chiefly to increased muscular action, an animal when stand-

FIG. 14.—HEAVILY-FED ANIMALS ORDINARILY HAVE AN EXCESS OF HEAT

Heavily-fed fattening steers thrive best with no shelter except an open shed, but animals being carried thru the winter on scanty rations need warmer quarters. (From *Prairie Farmer.*)

ing may produce 30 per ct. more heat than when lying down. Exposure to cold winds, especially with animals having scanty coats, increases the need for body fuel. Animals with coats wet by rain or snow lose still more heat from their bodies, for the cold water must be warmed and evaporated by heat produced thru the burning of food in the body. With heavily-fed fattening animals this may not cause any waste of food nutrients, for much more heat is being produced in the mastication, digestion, and assimilation of their heavy rations than is ordinarily needed to warm the body. On the other hand, animals being carried thru the winter on scanty rations have no such excess of heat, and hence much feed may often be saved by protecting them from cold winds and storms.

II. Requirements for Protein

Protein required for maintenance.—The demands of the body for fuel and energy can be met thru feeding carbohydrates and fat. However, an abundant supply of these nutrients alone will not prevent starvation, for there must also be a supply of protein to replace that lost each day from the body; that is, to repair the protein tissues. In view of the high cost and relative scarcity of protein in feeding stuffs, it is important to know the smallest amount of this nutrient which will maintain animals in good health. When plenty of carbohydrates and fat were supplied to serve as body fuel, animals have been maintained for long periods on surprisingly small amounts of protein. For example, at the Pennsylvania Station [1] Armsby maintained steers on only 0.4 to 0.6 lb. of digestible protein daily per 1,000 lbs. live weight without harm. It is not well, however, to supply only the theoretical minimum of protein to animals for long periods. Some allowance must be made for the difference in composition of feeding stuffs and the varying abilities of animals to digest the same feeds. We should further remember that the various proteins differ in composition and that some are so unbalanced as to have but low value for repairing body tissues. In numerous experiments animals have never been successfully maintained on gelatin, a protein which lacks two amino acids and contains only small amounts of others. Besides supplying protein to replace the daily waste from the tissues and organs of the body, there should be provision for the growth of the hair, hoofs, and wool—all of a protein nature. In general, protein is a cell stimulant and a supply somewhat above the minimum promotes the health of the animal.

The wisdom of not limiting the protein supply to the theoretical minimum for long periods has been shown by the experience of

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[1] Principles of Animal Nutrition, 1903, p. 142.

Haecker of the Minnesota Station.[2] He found that dairy cows under good care and otherwise liberal feeding continued a good flow of milk for long periods on a very small allowance of crude protein. After some years of such feeding, however, the vitality of these cows was so undermined that they became physical wrecks long before their time. Even when sufficient protein is fed to insure good health, the amount required to maintain mature resting animals is not large compared with the need for carbohydrates and fat for body fuel. The maintenance rations for such animals may therefore have a relatively wide nutritive ratio. For example, rations for maintaining full-grown steers may have as wide a nutritive ratio as 1:10 or even 1:16 and for horses as wide as 1:8 or 1:9. (See Appendix Table V.)

When more protein is fed than is needed to repair the tissues of the body, the nitrogen is split off the excess portion and excreted in the urine. The non-nitrogenous part which remains is not wasted, but may be used for body fuel just as are carbohydrates and fat, or it may be changed into glucose and possibly finally stored as fat in the body.

Can amids replace protein?—Whether the group of nitrogenous compounds, more simple than the proteins, which are included under the term amids (see Page 10), can serve the same purpose in the body as the true proteins, is still a disputed question. Numerous trials have shown that animals cannot live on a single amid as the sole source of nitrogen. However, it is reasonable to believe that when a mixture of amids in a feeding stuff contains all the different amino acids (the protein building-stones) needed to form body protein, these amids can then be used in the same manner as true protein for the repair of body tissues and for the formation of new protein tissue. This belief is upheld by the following: Nearly half the nitrogen in corn silage and only about 15 per ct. of that in dried corn forage is in amid form. Yet, based on the dry matter content, corn silage is somewhat more valuable than dry corn forage as a feed for dairy cows, which require a liberal supply of crude protein. Likewise, the amids are abundant in grass, roots, and silage, which are especially useful for growing and pregnant animals and for those producing milk or wool—all of which are in particular need of abundant protein.

III. REQUIREMENTS FOR MINERAL MATTER

Importance of mineral matter.—The necessity for an ample supply of mineral matter is shown by feeding animals rations freed as far as possible from it. Even tho the rations contain an abundance of protein, carbohydrates, and fat, the animals will die thru mineral starvation, and generally the end will come more quickly than if no food at all is given. Mineral matter is found in all the vital parts of the body. The life centers of all the cells are rich in phosphorus and the skeleton is largely composed of calcium (lime) combined with phosphorus. As we have seen, the power of the blood to carry oxygen is due to hemoglobin, an iron-protein compound in the red blood corpuscles. In the stomach, the pepsin acts only in the presence of hydrochloric acid, a mineral compound derived from mineral salts in the blood.

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[2] Minn. Buls. 71, 79, 140.

A simple experiment often performed in the laboratory will illustrate the manner in which mineral salts control life processes. If the heart, still beating, is removed from a frog and placed in a solution of pure sodium chlorid (common salt), its beats soon fade out. Now, if a small amount of a calcium salt (lime) be added to the solution, the heart will at once begin to beat again, and will continue in rhythmical contraction for several hours. Unless a small amount of a potassium salt is likewise added, the beat will not, however, be normal, the heart failing to relax quickly and completely enough after each contraction. The relaxations will become more and more feeble, until the heart stops in a contracted state. Not only must potassium be present, but there must be a correct proportion between the amounts of calcium and potassium. If too much potassium is added, the heart will fail to contract properly and finally will again stop beating, but this time in a state of complete relaxation.

The common feeding stuffs contain all the necessary mineral salts, at least in small amounts. As a rule, the roughages, except some of the straws, are much richer than the grains in mineral matter. Moreover, the body is probably able to use many of the mineral compounds over and over again, taking them back again into the circulation after having been used. Therefore, for animals which have finished their growth, the usual rations containing roughage furnish sufficient mineral matter, except common salt. As shown later, it is advisable to supply farm animals common salt in addition to that in their feed. Since large amounts of calcium (lime) and phosphorus are needed to build the skeleton, these elements may fall short in rations for young animals.

Calcium and phosphorus.—Over 90 per ct. of the mineral matter in the skeleton consists of calcium and phosphorus. When the supply of either of these is low in the feed, the skeleton acts as a storehouse, doling out these mineral elements so that the life processes of the body may continue normally for a time. But such withdrawal of mineral matter from the bones makes them porous and brittle. Indeed, in certain localities where the hay and other roughages are unusually low in calcium and phosphorus, due to the poverty of the soil in these elements, the bones of farm animals may become so brittle that they break with surprising ease. Growing animals, whose bones are rapidly increasing in size, suffer from a lack of these mineral elements sooner than mature animals. Because they are fed chiefly on the cereal grains, which are low in calcium, pigs fail to receive enough calcium more often than do calves, colts and lambs, which eat hay and other roughage as well. Of grown animals, those carrying their young or producing a heavy yield of milk are most apt to suffer from a lack of calcium or phosphorus.

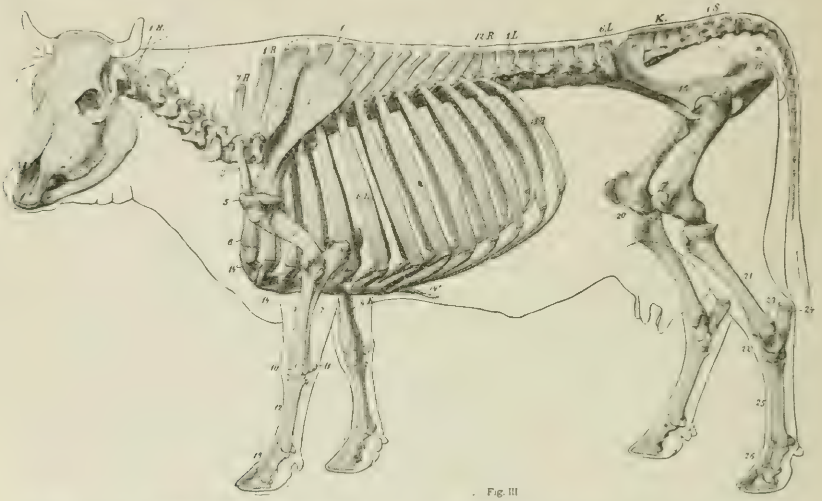

FIG. 15.—FARM ANIMALS NEED AN AMPLE SUPPLY OF MINERAL MATTER

Over 90 per ct. of the mineral matter in the skeleton consists of calcium and phosphorus. In certain rations the amount of these mineral elements may be insufficient for health. (From Ellenberger.)

Fortunately, roughage from the legumes, such as clover, alfalfa, and cowpea hay, is rich in phosphorus and especially in calcium. Thus animals fed legume hay commonly receive plenty of these mineral elements. Straw, chaff, the various root crops, molasses, and the cereals and their by-products, such as bran or middlings, are generally low in calcium. Beet pulp, potatoes, molasses, straw, and chaff are low in phosphorus, while the cereals and brans, oil cakes, and slaughter-house and fish waste carry it in abundance. When there is danger of a deficiency of either calcium or phosphorus, it is wise to add a supply to the ration. Calcium may be furnished cheaply in ground limestone or wood ashes, and both calcium and phosphorus in ground rock phosphate, ground bone, or bone ash. As shown in Chapter XXVII, it is wise to keep a supply of mineral matter before pigs at all times, especially when confined to pens.

Common salt.—In spite of the well-known hunger of herbivorous animals for salt, practical men have differed as to the necessity or advantage of adding it to the ration. It is now agreed, however, that salt should be supplied regularly to farm animals. It not only serves as a spice to whet the appetite and add to the palatability of many feeds, but it also stimulates the digestive glands and prevents digestive disturbances. At least for cows in milk, a supply of salt in addition to that contained in the feed is absolutely necessary for health. This was shown in experiments by Babcock and Carlyle at the Wisconsin Station[3] in which dairy cows, well fed otherwise, were given no salt for periods as long as a year. After varying lengths of time, a complete breakdown occurred, marked by loss of appetite, lusterless eyes, a rough coat, and a rapid decline in body weight and milk yield. When salt was supplied, recovery was rapid.

Animals allowed free access to salt or supplied with it at frequent and regular intervals will take only enough to meet the needs of the body. Animals that have not been supplied with salt for some time and are then allowed all they will eat, may consume too much. This creates an abnormal thirst and causes excessive drinking, which may lead to digestive disturbances. Cows in milk and sheep show the greatest need of salt, horses, fattening cattle, dry cows, and stock cattle require less, and pigs but little. The needs of each class of farm animals for salt are discussed in the respective chapters of Part III.

IV. Additional Requirements of Animals

We have thus far considered in detail only the requirements of farm animals for crude protein, carbohydrates, fat and mineral matter. However, just as vital as the demands for fuel and repair material, which are met by these nutrients, is the need for air, water, and vitamines.

Air.—While animals survive starvation for considerable periods, lack of air brings immediate death, since a continuous supply of oxygen is required for all vital processes. Each hour a cow breathes in about 117 cubic feet of air, making over 2,800 cubic feet each 24 hours. For health, a stable where animals are confined should not contain more than 3.3 per ct. of air which has been previously breathed. To provide cows with air of this purity, there should pass into the stable for each cow not less than 85,000 cubic feet of air each 24 hours. These figures show the necessity of providing a good system of ventilation for animals confined in closed stables, as are horses and dairy cattle during the winter in the northern states.

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[3] Wis. Rpt. 1905.

Water.—Animals can live much longer without solid food than without water. An abundant supply of water is necessary for all the vital processes of the body, such as the digestion and absorption of food nutrients and the removal of waste from the body. As already shown, water is also an agent in regulating the body temperature, both thru the vapor given off by the lungs and the evaporation of sweat from the surface of the body.

Scientists agree that farm animals should have all the water they will drink at regular intervals, for they do not take it in excess unless they are forced to live on watery foods or are given salt irregularly. The water for stock must be fresh and pure to avoid disease. All water drunk must be raised to the temperature of the body, thus consuming heat. Warming cold water taken into the body does not necessarily mean that more food must be burned, for animals produce a large amount of heat in the work of digesting food and converting the digested matter into body products or work. Due to this, many animals create an excess of body heat. Comfortably housed and well-fed steers and dairy cattle may produce more heat thru this means than is needed to warm their bodies and the excess may go to warm the water they drink, so that no food is directly burned for that purpose. However, when animals are watered but once a day they then drink a large amount. In winter if the water is cold this makes a sudden demand for a large amount of heat, which may exceed the amount of excess heat being produced in the body. Food must then be burned simply to warm the water, even tho thereafter an excess of heat may be produced in the body. For this reason, feed may be saved by watering frequently animals unduly exposed to cold and those fed scanty rations, or else by warming the water. During severe winter weather cows producing a heavy yield of milk need more water than they are apt to drink if it is supplied too cold. Under such conditions their water should be warmed.

Vitamines.—Within the past few years investigators have made some of the most important discoveries in the whole field of animal nutrition. They have found that the classes of nutrients previously discussed—proteins, carbohydrates, fats, and mineral matter—are not all that is necessary to make a satisfactory ration. Just as essential as these nutrients are certain compounds called "vitamines," the composition of which is unknown. Thus far, the existence of 3 different vitamines has been discovered: (1) the fat-soluble vitamine; (2) the water-soluble vitamine; and (3) the vitamine which prevents scurvy.

It has been found that when animals are fed upon feeds which have been freed from fatty substances they fail to grow or thrive and eventually die. If such fats as lard, olive oil, or commercial cottonseed oil are added to the ration no improvement results, but if butterfat, milk, egg fat, or kidney fat is supplied the diet is made complete and normal growth is resumed. These fats contain *the fat-soluble vitamine*, which is necessary for life. The cereals are generally poor in this vitamine, as are also Irish potatoes, mangels, and sugar beets. Most fortunately for economical stock feeding, the leafy parts of plants are rich in this vitamine. Because of this, farm animals consuming plenty of good roughage, such as legume hay, will undoubtedly secure plenty of it. There may perhaps in some cases be a lack of it with pigs reared without pasture or legume hay and with calves raised on milk substitutes. Yellow colored roots, such as carrots and sweet potatoes, are rich in the vitamine, and it has been found recently that yellow corn contains much more than white corn.

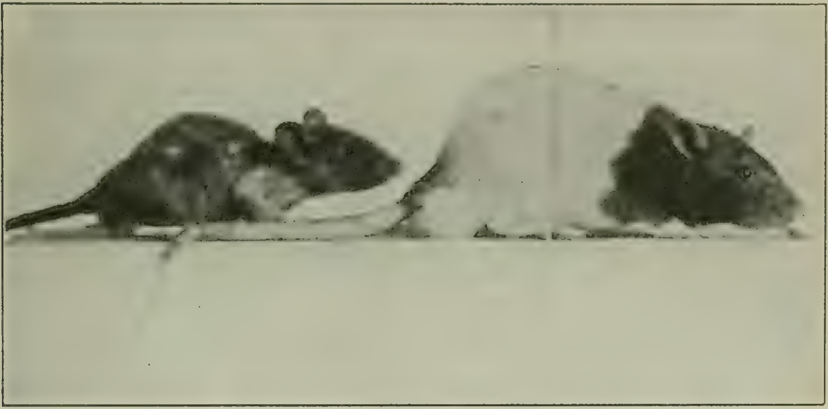

Fig. 16.—COMMONLY UNAPPRECIATED SUBSTANCES ARE NEEDED FOR GROWTH

Both rats were fed "balanced rations" containing an abundance of suitable protein and mineral water. The rat on the right, given butter fat in addition, grew thriftily, while the one on the left, fed cottonseed oil, which lacks the mysterious substance present in butter fat, failed to grow. (From McCollum, Wisconsin Station.)

The second vitamine is soluble in water, and is therefore called *the water-soluble vitamine.* When there is an insufficient amount of this vitamine in the food, the disease known as beri-beri is produced. This malady seriously affects humans, causing general weakness and even paralysis, in districts of the Orient where the inhabitants live mainly on polished rice. When unpolished rice, carrying the germ and part of the husk, is eaten instead, this disease does not occur. Animals affected with this disease are cured by giving them the water extract of rice germ or of other foods rich in the water-soluble vitamine. An abundance of this vitamine has been found in most ordinary foods, such as the cereals and other seeds, milk, eggs, and the leafy portions of plants. It is not destroyed by drying or exposure to light. Therefore all ordinary rations for live stock will contain an ample supply of the water-soluble vitamine.

The third vitamine, which prevents scurvy, is of little or no importance for farm animals, except possibly swine. Farm animals do not require it or need so little that all usual rations furnish plenty. Humans, monkeys, and guinea pigs must be furnished this vitamine, or scurvy will result. It is supplied by milk and fresh fruits, vegetables, and meat, but is low in the cereals. Long cooking or drying at high temperatures destroys it.

Our knowledge of vitamines is yet too fragmentary for us to predict to what extent further studies on these interesting compounds may make it possible to devise more efficient rations for stock.

Feeding concentrates alone to animals.—By reason of their high ability to digest coarse roughage, ruminants are especially adapted to convert the coarse plant materials of no value for human food into useful products. Tho ordinarily it would be unprofitable to feed such animals solely on concentrates, the question whether they can be so maintained is of scientific interest. Dry dairy cows have been kept thru the winter in fair condition on corn meal with no hay. At first they were restless, but soon quieted down and rumination, or chewing the cud, ceased. A 2-year-old steer was fed for nearly eight months exclusively on grain, and sheep are not infrequently fed only grain and roots. We may therefore conclude that mature ruminants can be maintained for considerable periods, if not indefinitely, on concentrates alone. With young ruminants Nature is less yielding, for all attempts to raise calves on milk and grain without hay or other roughage have ended in failure. Apparently some coarse feed is needed to fill the first three stomachs so they may develop properly.

Efforts to keep horses on oats alone were unsuccessful, the horses refusing the oats after a few days. Evidently horses cannot live on concentrates alone, even oats with their straw-like hulls. On the other hand, pigs have been raised on milk alone, tho this is not wise, as they may become decidedly unthrifty without some bulky feed.

Succulent feeds.—Numerous scientific trials and common farm experience have abundantly demonstrated the value of adding succulent feeds to the rations of farm animals. The beneficial effects of succulence, whether supplied as pasturage, silage, soilage, or roots, are many. Just as our own appetites are stimulated by fruits and vegetables, succulent feeds are relishes for the animals of the farm, inducing them to consume more feed and economically convert it into useful products. It is reasonable to hold that such palatable feeds stimulate digestion and it is well known that their beneficial laxative effect aids in keeping the digestive tract in good condition. Among the most important contributions of the experiment stations are their demonstrations of the economy of feeding silage to milch cows, fattening cattle and sheep, and of the possibilities of cheapening the cost of producing pork thru the utilization of suitable pasture. The merits

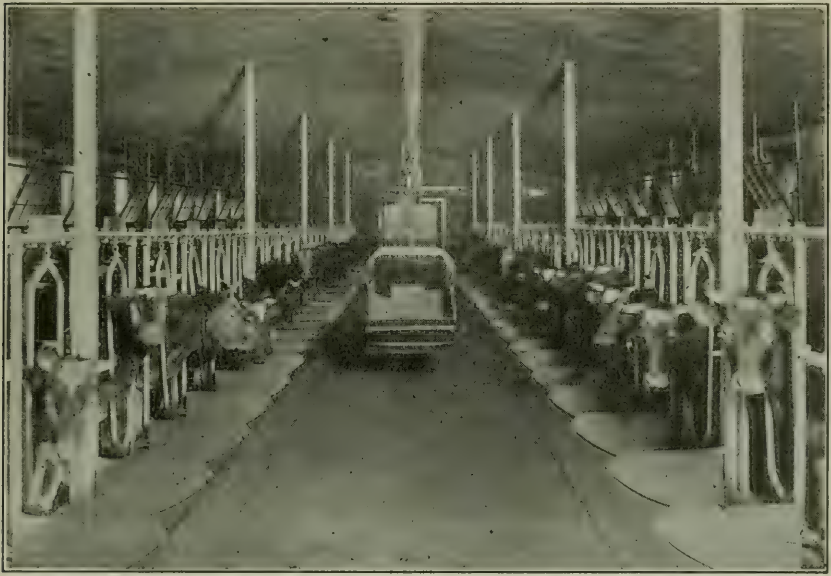

FIG. 17.—COMFORTABLE QUARTERS, SUNNY AND WELL-VENTILATED, INCREASE PROFITS

Comfortable, well-lighted, and well-ventilated quarters, and quiet and regularity in feeding are nearly as important as supplying balanced rations. (From *Guernsey Breeders' Journal.*)

of the various forms of succulence for the different farm animals are discussed in later chapters.

Exercise; light.—For the maintenance of health, exercise is essential. The only exceptions to this rule are fattening animals, soon to be marketed, which make more rapid gains if not allowed to move about too freely. Abundant exercise is of special importance with breeding animals. The exercise requirements of the various farm animals are discussed in the respective chapters of Part III.

Sunlight is an effective germicide. To prevent the contraction and spread of disease, it is therefore important that the stables be well-lighted. For fattening animals the quarters may be darkened somewhat, as this tends to keep them quiet and thus favors fattening.

Quiet and regularity.—Farm animals are creatures of habit, and once accustomed to a routine of living show unrest at any change. The stable and feed lot should be free from disturbance, and the administration of feed and water should be uniform in time and manner. Animals soon learn the feeding hour, and as it approaches the secretions pour from the various digestive glands in anticipation of the coming meal. Changes should be made gradually and only for good reason, for in all feeding operations a changing period is usually a losing one.

QUESTIONS

1. Define a maintenance ration. What four body needs must it meet?
2. Describe the production of heat in the body and state how it differs from the burning of fuel in a stove.
3. How do farm animals regulate the temperature of their bodies?
4. In maintaining a mature animal for what is most of the food used?
5. How wide nutritive ratios may rations for maintaining mature animals have?
6. What sort of feeds would you give a mature, idle horse?
7. Are amids and true proteins of the same value?
8. What mineral elements are most apt to be deficient in rations?
9. Name some feeds that are low and others that are high in calcium and phosphorus?
10. If a ration did not contain enough calcium or enough phosphorus, what would you add?
11. How has it been shown that cows must be supplied with common salt?
12. Why is a good system of ventilation necessary in stables?
13. How much water should farm animals be given? For what animals should it be warmed in winter?
14. Can animals be maintained on concentrates alone?
15. Discuss the importance of each of the three vitamines in stock feeding.
16. Discuss the value of succulent feeds, exercise, light, and quiet and regularity.

CHAPTER V

GROWTH AND FATTENING

I. Growth

We have seen in the preceding chapter that for maintaining mature animals but relatively little protein and mineral matter are needed to replace the small daily waste of these substances from the body. The requirements for young, growing animals are far different, for their bodies are increasing rapidly in both protein and mineral matter.

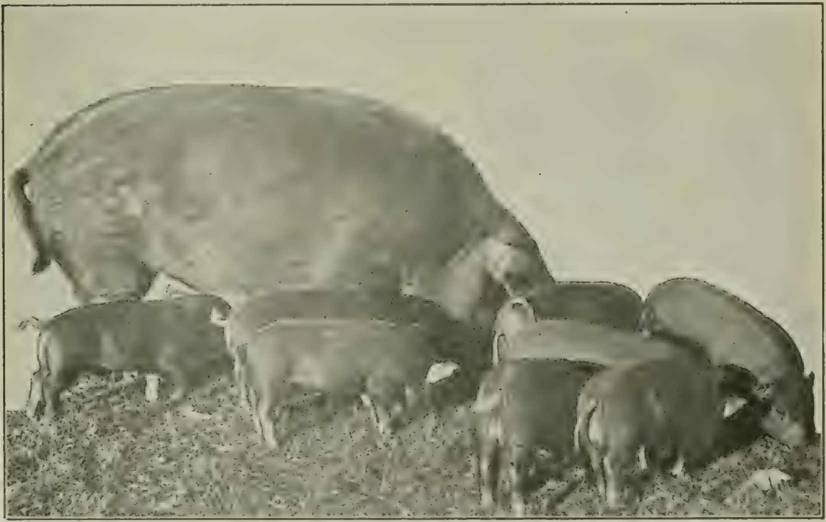

Fig. 18.—Young Animals Need Abundant Protein and Mineral Matter

Since the skeleton and protein tissues are steadily increasing in size during growth, young animals require feeds rich in protein and mineral matter. (From Fuller, Wisconsin Station.)

In the growing body and its organs considerable fat is also stored, especially if the animal is well fed. Therefore the growing animal, in addition to being supplied with enough food to maintain its weight, must receive additional nutrients to provide for the building of its body.

Requirements for growing animals.—The skin, muscles, ligaments, tendons, and internal organs of animals are almost wholly protein, as is a large part of the nervous system and the organic portion of the bones. During youth, all these parts steadily increase in size, and at the same time much mineral matter is built into the skeleton or is retained in the vital parts of the body cells. It is therefore clear that the rations for growing animals should contain a much larger proportion of protein and mineral matter than is needed in those for maintaining mature animals. After growth is completed, but little storage of protein or mineral matter can take place, for the skeleton, the muscles, and the internal organs have reached full development. However, if an animal is healthy but has poor muscular development, some increase in the size of the muscles can be made thru suitable exercise and an ample supply of protein. Beyond this, the only storage of protein which can occur is in the growth of the nitrogenous hair and hoofs, and the small amount of protein stored in the fatty tissues.

We have seen that maintenance rations may consist chiefly of roughage, which furnishes little net energy. On the other hand, for thrifty growth, the ration must be more concentrated (that is, must furnish more net energy) to provide for the energy stored in the growing tissues of the body in the form of protein and fat. Furthermore, the rations for growing animals must contain ample supplies of vitamines which have been discussed on Pages 58–60.

Milk the natural food for young mammals.—Since milk is Nature's food for the young of all mammals, it is reasonable to believe that it contains all the nutrients necessary to sustain life in the young, and that these are in proper proportion. A study of the composition of milk, as given in the following table,[1] will therefore aid in showing the requirements for growth.

Composition of normal milk and of colostrum milk

	Water Per ct.	Mineral matter Per ct.	Protein Per ct.	Sugar Per ct.	Fat Per ct.
Cow, normal milk...........	87.2	0.7	3.5	4.9	3.7
Ewe, normal milk...........	80.8	0.9	6.5	4.9	6.9
Sow, normal milk...........	81.0	1.0	5.9	5.4	6.7
Cow, colostrum milk........	74.5	1.6	17.6	2.7	3.6
Ewe, colostrum milk........	61.8	1.0	17.1	3.5	16.1
Sow, colostrum milk........	70.1	0.9	15.6	3.8	9.5

[1] Partly from König, Chem. Nahrungs und Genussmittel, Vol. I, 1903.

Milk contains an abundant supply of protein compared with the amount of other nutrients, having a nutritive ratio of 1:3.9, while the nutritive ratio of dent corn is 1 : 10.4. Milk is also much richer in mineral matter than are the cereal grains. The supply of lime and phosphoric acid, needed in large amounts in the growing skeleton, is especially liberal, these two constituents forming about half the total mineral matter. Milk also contains a liberal supply of the fat-soluble vitamine and of the water-soluble vitamine, both of which are necessary for animals. The sugar and fat in milk furnish concentrated energy and also supply nutrients for the formation of the fatty tissues of the body.

The first milk yielded by the mother, called *colostrum*, is thicker and far higher in protein and often richer in ash than ordinary milk. Colostrum is laxative and highly important for cleansing the alimentary canal of accumulated waste matter and properly starting the work of digestion. During the week following birth the composition of the milk gradually changes to normal.

These studies of the composition of milk teach that after weaning young animals should be given feeds similar to milk in composition: i. e., rich in protein and mineral matter. For this reason, legume hay and protein-rich concentrates, like wheat bran, wheat middlings, and linseed meal, are of high value for growing animals.

Protein must be of proper quality.—Only a few years ago scientists believed that an ample *quantity* of protein was all that was necessary for normal growth. Many recent experiments show, however, that not only must the *quantity* of protein in the food be abundant, but it must also be of the proper *kind* or *quality*, if the animal is to grow thriftily. We have seen in Chapter I that the proteins are made up of many different amino acids (the protein building stones) and that the amounts of these different amino acids in various plant proteins differ widely. Some are well-balanced, containing considerable amounts of all the amino acids, while in others certain of the amino acids may be entirely lacking. All the different amino acids are needed to form the proteins of the body, but animals are able to manufacture only one of these amino acids in their bodies from other compounds of the food. Therefore, for normal growth the food must furnish all the necessary amino acids, with the possible exception of a single one.

The following illustration will show the conditions an animal may meet in forming body proteins from the mixture of amino acids resulting from the digestion of the food protein: Suppose we are building a brick wall in a certain pattern which requires that 1 brick in 10 have a green end. If we are using as our source of material a pile of bricks resulting from the taking down of another wall, in which only 1 brick in 50 had a green end, it is evident that we will soon have to stop rebuilding, tho having many perfect bricks left, because none have the green end required for the pattern.

Some proteins, such as the principal ones of wheat, furnish as much as 40 per ct. of a single amino acid, which forms only 14 per ct. of the animal proteins. When such protein alone is given to growing animals, obviously a considerable part will be wasted and growth will be checked. Proteins which entirely lack some of the necessary amino acids will produce no growth whatever when fed alone. However, if the necessary amino acids are added to the ration, the animal will be able to continue growth.

The various incomplete or unbalanced proteins do not all lack the same amino acids. Hence, when two incomplete proteins are combined one may supplement the deficiencies of the other and better growth be made than on either alone. For example, experiments with pigs[2] have shown that when corn alone was fed but 23 per ct. of the protein was built into body protein, and when only linseed meal was fed, but 17 per ct. When a mixture of three-fourths corn and one-fourth linseed meal was given, 37 per ct. of the protein was used in growth. Thus corn and linseed meal help to correct the deficiencies of each other. Still more improvement was made when corn was combined with feed containing better balanced proteins. For example, on corn and skim milk, 72 per ct. of the protein in the feed was built into body protein. It is doubtless partly due to this supplementing action of the proteins in different feeds that better results are often secured in stock feeding when a variety of feeds is used than with only one or two. The various chapters of Part III show the combinations of feeds which are best for the different classes of growing animals.

Mineral matter required for growth.—It has already been shown that the young animal, growing rapidly in skeleton and body tissues, needs a liberal supply of mineral matter, especially calcium (lime) and phosphorus. Enough must be furnished not only to provide for the growth of the muscles, bones, etc., but to replace the small daily loss from the body.

The injurious effects of a lack of mineral matter are shown in a trial at the Wisconsin Station[3] in which one lot of growing pigs was fed wheat bran from which most of the phosphorus had been removed by washing, together with wheat gluten and rice, both of which feeds are extremely poor in mineral matter. Other lots were fed the same ration plus ground rock phosphate or bone ash, which supplied ample calcium and phosphorus. For a considerable period all the pigs

[2] McCollum, Jour. Biol. Chem., 19, 1914, p. 323; information to the authors.

[3] Hart, McCollum and Fuller, Wis. Res. Bul. 1.

throve fairly well, but as time went on those fed the ration poor in mineral matter fell behind the others. They had no appetite and disliked to stand up; later they lost control of their hind quarters and had to be carried to the trough at feeding time. When the pigs were slaughtered, it was found that those fed insufficient phosphorus had light, weak bones, while those receiving ground rock phosphate or bone ash had strong, heavy ones.

Since the common feeds which are high in protein are also rich in phosphorus, probably plenty of phosphorus will be furnished when rations are balanced according to the usual feeding standards. The calcium supply for calves and lambs will usually be ample when hay and the cereals form the greater part of the ration. Deficiencies may occur in regions where the roughages are unusually low in calcium, or when large amounts of such roughages as wheat straw, barley straw, or timothy hay are fed. Where pigs are fed exclusively on the cereal grains, especially corn, the calcium supply will usually be too low. As shown in the preceding chapter, when calcium alone is lacking, it may be supplied in legume hay or in the form of ground limestone. If only phosphorus, or if both calcium and phosphorus are lacking, these may be furnished in ground rock phosphate, ground bone, or bone ash.

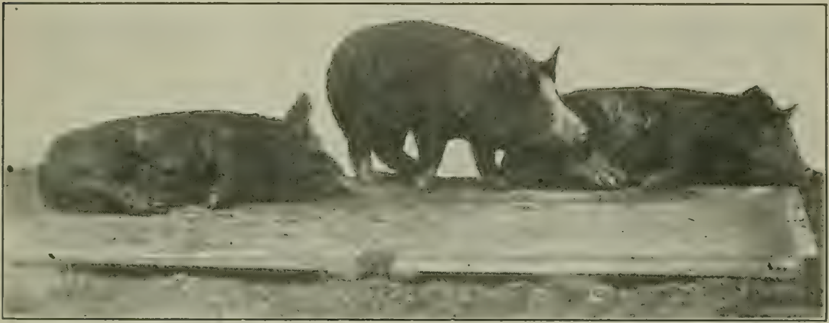

FIG. 19.—PIGS FED A RATION LOW IN PHOSPHORUS

These young pigs, fed a ration very low in phosphorus at the Wisconsin Station, are stunted and have lost control of their hind quarters. Pigs fed the same ration with ground rock phosphate in addition grew thriftily. (From Hart, Wisconsin Station.)

Utilization of food by young animals.—The gains made by thrifty, well-fed young animals are much larger and more economical, based on live weight and food consumed, than those of mature animals. For example, an unweaned calf may gain 2 to 3 lbs. daily for each 100 lbs. of body weight, while a daily gain of 0.3 to 0.4 lb. per 100 lbs. of body weight is large for a mature fattening steer. The more rapid gains of young animals are due to several causes. They consume more food per 100 lbs. live weight and thus have more food left to make gain after their bodies are maintained. Young lambs fed cow's milk have even stored nearly three-fourths of the protein, over 90 per ct. of the calcium, and about three-fourths of the phosphorus supplied in their food. The flesh of young animals is more watery than that of older ones. Hence, each pound of the gain they make contains less dry matter than in the case of older animals.

II. FATTENING

The object of fattening.—We all know that the lean meat from a well-fattened animal is better flavored and more juicy and tender than from a lean one. This improvement in the quality of the lean meat, and not the storage of thick masses of fat, is the main object in fattening animals before they are slaughtered for meat. To some extent during growth, and especially during fattening, fat is stored in the lean-meat tissues, chiefly between the bundles of fibers of which the muscles are composed. This storage of fat, which forms the so-called "marbling" of meat, adds to its tenderness, juiciness, and flavor, besides increasing the digestibility and nutritive value.

What fattening is.—The fattening of animals is what the term implies, chiefly the laying on of fat. Many years ago Lawes and Gilbert of the Rothamsted (England) Station,[4] by analyzing the bodies of animals slaughtered at various stages of fattening found that the increase of steers when nearly full grown was about two-thirds fat, and only 7.7 per ct. protein and 1.5 per ct. mineral matter. With pigs the proportion of fat was even greater. The younger the animals are when they are fattened, the greater will be the storage of protein and mineral matter. This is shown in the following table, which shows the results of experiments at the Missouri Station.[5] There is first given the composition of the carcass of a 748-lb. steer in thrifty growing condition, followed by the composition of the gains made by similar steers during fattering.

Composition of unfattened steer and gains during fattening

	Fat Per ct.	Protein Per ct.	Ash Per ct.	Water Per ct.
Carcass of unfattened steer	18.6	18.8	5.7	56.4
First 500 lbs. of gain	48.6	11.9	2.0	37.6
Second 500 lbs. of gain	75.6	5.2	1.5	17.8

[4] Jour. Roy. Agr. Soc., 1860.

[5] Waters, Mumford, and Trowbridge, information to the authors.

While the carcass of the steer killed before fattening contained only 18.6 per ct. fat, the first 500 lbs. of gain was nearly half, and the last 500 lbs. over three-fourths fat. During the first 500 lbs. of gain, 11.9 per ct. of the increase was protein, but in the last 500 lbs. of gain only 5.2 per ct. was protein. The storage of ash was likewise less as the animal matured.

How body fat is formed.—Since fattening is chiefly a storage of body fat, in studying the feed requirements of fattening animals it is most important to learn from what substances in the feed this body fat may be formed. By numerous feeding experiments it has been shown that after enough nutrients have been supplied to maintain the body, any excess—no matter whether fat, carbohydrates, or protein—may be transformed into body fat.

The fat in the food is not commonly stored in the body without being altered. As a result, even when all are fed the very same feeds, the fat formed by the steer, sheep, and pig will differ considerably in chemical properties. All the digested fat taken into the body beyond that required for maintenance cannot be deposited as body fat, since considerable losses always occur thru the energy used up in digestion and assimilation. The largest part of the fat stored in the body is undoubtedly formed from the carbohydrates of the food, for these are the most abundant nutrients in all common rations. When more protein is furnished than is needed for the repair of the body tissues, the remainder may, after the nitrogen is split off, also be changed into body fat.

The ration for fattening.—Since the fattening of mature animals consists mainly in the storage of fat, there is no demand for a large supply of protein for fattening animals. However, it is not advisable to feed a ration having a wider nutritive ratio than 1:10 or 1:12, for, as we have seen in Chapter III, when less protein than this is fed the digestibility of the ration is decreased. Since any excess of protein can be changed into fat, where protein-rich feeds are cheaper than those of a carbonaceous character, it may be profitable to feed rations having a narrow nutritive ratio. For example, in the South, where cottonseed meal is frequently the only concentrate used, fattening steers are often fed rations having nutritive ratios of 1:4, or even narrower. Animals in thin flesh should at first receive a liberal supply of protein so that their muscular tissues may develop.

Because young animals make the most economical gains, most of the meat-producing animals in this country are fattened and marketed before maturity. Such animals add not only fat but also considerable lean meat to their bodies as they fatten, and therefore require more protein than mature animals. From a survey of the many feeding trials carried on by the experiment stations of this country, the authors believe that 2-year-old steers should not be fed rations wider than 1:7 to 1:7.8 when being fattened. Depending on their age, fattening lambs should not be fed rations wider than 1:6 to 1:8. (See Appendix Table V.)

Factors influencing fattening.—The storage of fat in an animal depends primarily upon the quantity of food consumed in excess of maintenance and growth requirements. Fattening may take place at any age, tho the tendency of young animals to grow greatly reduces the proportion of food usually available for fattening. Supplying an abundance of feeds that are palatable, concentrated, and largely digestible aids rapid fattening, because a large surplus of nutrients then remains after supplying the body needs.

The disposition of an animal to fatten depends upon breed and temperament. While a wild animal, nervous and active, can be fattened only with difficulty, domesticated animals are more quiet and usually fatten readily. The restless animal is rarely a good feeder, while the quiet one, which is inclined to eat and lie down, will show superior gains. This is not due to difference in digestive powers, but rather to the fact that the quiet animal has, from a given amount of feed, a greater surplus of nutrients for fat building. Fattening animals must not be allowed to exercise too much as this wastes nutrients which they might store in their bodies.

Returns from feed.—The following table[6] shows the amount of food suitable for man returned by the different classes of farm animals from each 100 lbs. of digestible matter consumed:

Human food produced from 100 lbs. of digestible matter consumed

Animal	Marketable product Lbs.	Edible solids Lbs.	Animal	Marketable product Lbs.	Edible solids Lbs.
Cow (milk)	139.0	18.0	Poultry (eggs)	19.6	5.1
Pig (dressed)	25.0	15.6	Poultry (dressed) .	15.6	4.2
Cow (cheese)	14.8	9.4	Lamb (dressed) ...	9.6	3.2
Calf (dressed)	36.5	8.1	Steer (dressed)	8.3	2.8
Cow (butter)	6.4	5.4	Sheep (dressed) ...	7.0	2.6

The table, which presents one side of a most complicated problem, shows that for 100 lbs. of digestible nutrients consumed the cow yields about 139 lbs. of milk, containing 18 lbs. of solids, practically all digestible. She easily leads all farm animals in her power to convert the crops of the field into human food. The pig produces about 25 lbs. of dressed carcass. Allowing for water, bone, and gristle, there remains over 15 lbs. of edible dry meat. The steer and sheep yield less than 10 lbs. of dressed carcass, nearly half of which is water. Deducting this and the bone and gristle, there remains only from 2.6 to 3.2 lbs. of water-free edible meat.

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[6] Jordan, The Feeding of Animals.

The economy of gains by animals when young is evident on comparing the figures for the calf with those for the steer, and those for the lamb with those for sheep. It should also be noted that the pig excels all other meat-producing animals in the efficiency with which he produces human food. This is largely because he eats more feed per 100 lbs. live weight, and also because his food is more concentrated and digestible. Both these factors increase the proportion of the food consumed which can be used for producing gain.

III. Studies on Growth and Fattening

Feeding pigs corn only.—In 1884 Sanborn of the Missouri Agricultural College[7] carried on trials in which growing pigs fed exclusively on corn meal were compared with others fed on corn meal and either wheat middlings or dried blood. The corn-meal ration furnished an abundance of easily digested carbohydrates and fat, but was deficient in protein and mineral matter. The addition of dried blood or wheat middlings to corn meal formed a ration rich in protein and mineral matter as well as in carbohydrates and fat. Compared with the corn-fed pigs, those getting rations rich in protein had a larger muscular development and more blood, and some of their internal organs were larger.

Realizing the fundamental importance of Sanborn's studies, the senior author[8] conducted numerous trials at the Wisconsin Station in which dried blood, wheat middlings, field peas, and skim milk, with or without corn meal, were fed in opposition to corn meal alone. Similar trials were conducted at the Kansas and Alabama Stations and in France. Thus at 5 widely separated points pigs were fed rations rich in protein and mineral matter, usually containing some corn meal, in opposition to corn meal alone, which is rich in carbohydrates and fat but low in protein and mineral matter.

Feeding corn alone not only greatly decreased the gains of the pigs but also greatly modified the composition of their bodies. As a rule, the pigs getting only corn had a smaller amount of blood and smaller livers and other internal organs per 100 lbs. of carcass than did those fed the rations containing ample protein and mineral matter. The bones of the corn-fed pigs were also abnormally weak. In the first Wisconsin trial their thigh bones broke at an average pressure of 380 lbs. for each 100 lbs. of carcass, while those fed milk, dried blood, and middlings broke at about 500 lbs.—a difference of 32 per ct. in favor of the rations rich in protein and mineral matter. The pigs given the protein-rich feeds had nearly 30 per ct. more blood for each 100 lbs. of carcass than those fed corn alone, and their livers, kidneys, and tenderloin muscles were also larger, showing that a superior muscular development was associated with the larger internal organs, more blood, etc. The carcasses of the corn-fed pigs, on the other hand, contained a greater proportion of fat.

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[7] Mo. Buls. 10, 14, 19.

[8] Wis. Rpts. 1886, '87, '88, '89.

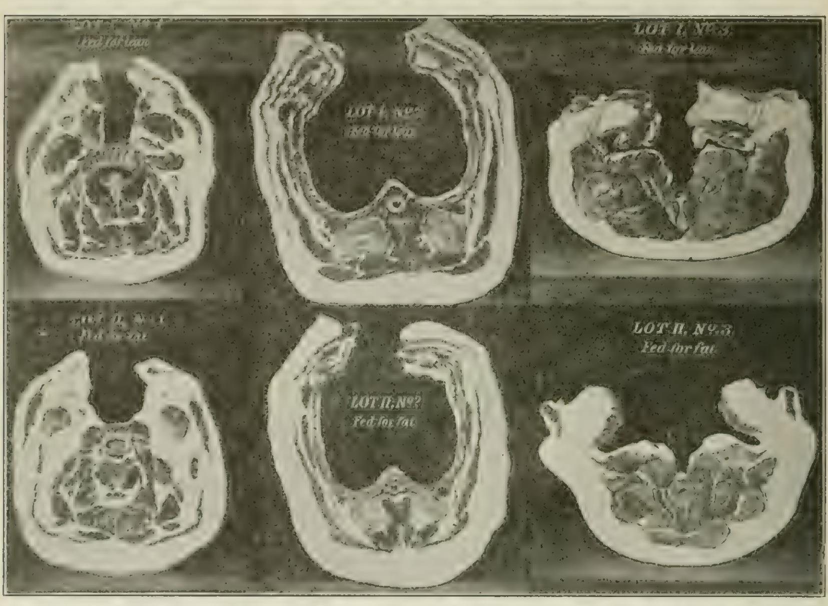

FIG. 20.—PIGS FED CORN ALONE DO NOT DEVELOP NORMAL CARCASSES

Upper row, cross sections of carcasses of pigs fed for lean; i. e., on well-balanced ration, by the senior author at the Wisconsin Station. Left, section at shoulder; middle, section between fifth and sixth ribs; right, section at loins. Lower row, carcasses of pigs fed corn alone. Note larger size of muscles of pigs fed well-balanced ration.

These experiments show the plastic nature of the bodies of young, growing animals. Immature animals living on such unsuitable food may survive for a long time, but they develop bodies that are dwarfed in size and made unnaturally fat. Nature's plan is first to grow the body framework and afterwards to lay on the fat, if food be abundant. The experiments point to the reasonable, important, and far-reaching conclusion that if a pig or other young animal is improperly fed so as to injure its bones, muscles, and vital organs even a very little, and the process is repeated during several generations, the effects will become marked and strikingly injurious. The practical lesson is taught that young animals should be fed a combination of feeding stuffs that will allow normal growth. This calls for a ration containing crude protein and mineral matter not only in ample amount, but also of suitable composition for the rapid formation of body tissues. When growth is completed, the food supply may then consist largely of carbohydrates and fat, which are the cheap and abundant sources of animal fat.

Growth under adverse conditions.—Extensive experiments carried on at the Missouri[9] and Kansas[10] Stations are of much interest in showing what happens when young animals are fed only enough feed to maintain their weights. Due to the impulse toward growth, young steers fed scanty rations continued to grow in height, tho not gaining in weight. In this effort the fat stored in the body was withdrawn and used up as body fuel, the animals becoming thin in flesh as the scanty feeding progressed.

For 70 to 120 days, depending on how vigorous they were and how much fat they carried, young steers fed only enough to maintain their weight gained as rapidly in height as others on full feed. After this period the increase in height became less rapid, ceasing altogether in from 6 months to a year and half, by which time the animals had become quite thin and had burned up all the fat in their bodies which was not absolutely necessary to life. Growth on scanty rations is not due directly to the fat re-absorbed from the body. The animal burns its stored fat to support the body, and the scanty protein supply in its food is used for building body tissue.

As a result of these studies Waters of the Kansas Station points out that a young animal may reach normal size by any or all of the following ways:

1. By growing steadily from birth to maturity.
2. By storing fat during a period of abundant food supply, which will help to tide over a limited period of sparse food supply without serious checking of growth.
3. By prolonging the growth period.
4. By an increase in the rate of growth during a period of liberal feeding following a period of scanty feeding and low gain.
5. By using its food more efficiently. Apparently when an animal is kept for a long period on scanty food, it gets on a more economical basis than when liberally fed. A ration which is at first insufficient

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[9] Waters and Trowbridge, Proc. Prom. Agr. Sci. 1908; information to the authors.

[10] Waters, Cochel, and Vestal, Kansas Industrialist, May 10, 1913; Apr. 18, 1914; and information to the authors.

to maintain an animal may be capable later of keeping the same animal at a constant body weight, and still later of causing a small gain.

Effects of checking growth.—Numerous experiments have been carried on at the Kansas Station to determine the effect on the later development of pure-bred beef steers of checking their growth by under-feeding. It was found that supplying a young, growing animal with a scant ration for only a short period will have no permanent effect on its development. Even when insufficient feeding is

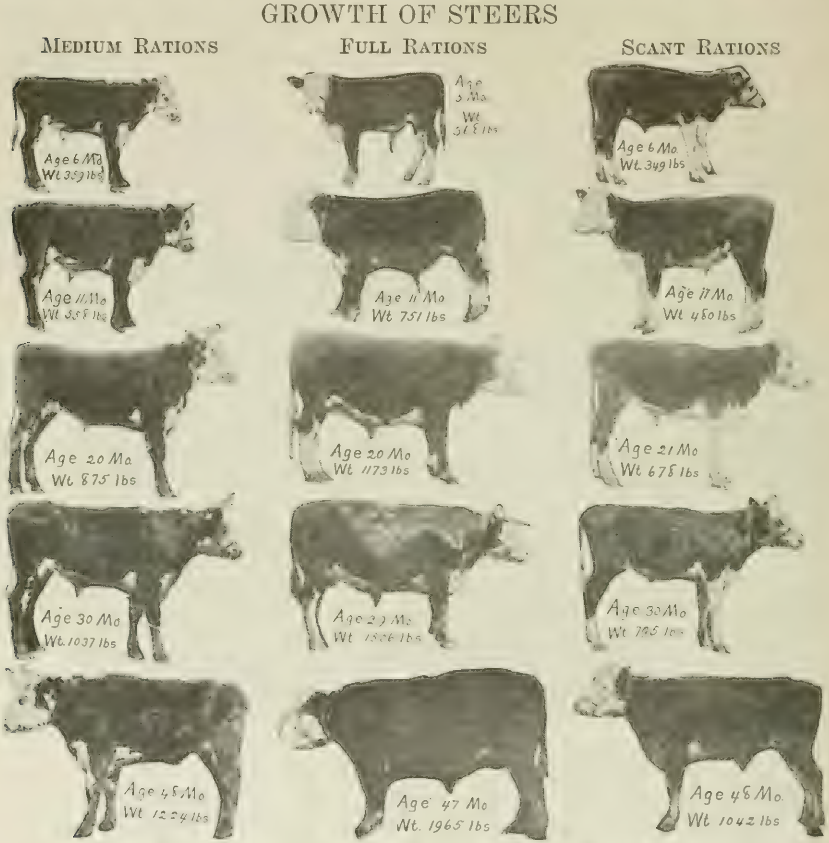

Fig. 21.—Scant Feeding Stunts Growing Animals

The steer in the middle row of pictures, fed a full ration, weighed 1,965 lbs. at 47 months. The steer at the left, fed a medium ration, weighed only 1,224 lbs., and the one at the right, fed a scant ration, but 1,042 lbs. Note the stunted appearance of the latter steers at the end of the trial. (From Missouri Station.)

continued for a year or longer, the animal will recover to a surprising extent when placed on liberal feed, making unusually rapid and economical gains.

However, while a steer whose growth has been checked for a year or more may grow nearly as tall as one always well fed, it is almost certain to have a smaller digestive capacity, narrower hips, flatter ribs, heavier shoulders, and lighter hind quarters, even when well fattened. The blocky form of the highly developed beef animal has evidently been caused by broadening the animal thru liberal feeding while young. If the feed is insufficient to distend the digestive tract and force out the ribs and hips while the body is yet plastic, then the animal will never later reach the desired conformation of the true beef type.

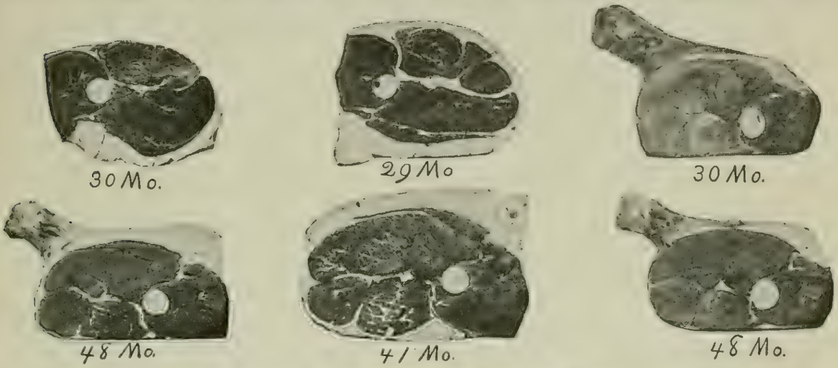

FIG. 22.—ROUND STEAKS FROM STEERS VARIOUSLY FED

Left, from steers fed medium ration; middle, from steers fed full ration; right, from steers fed scant ration. Note large size and well-marbled appearance of muscles from the full-fed steers and the scarcity of fat in the meat from the steers fed the scant ration. (From Missouri Station.)

These studies on growth are highly significant to the stockman. They show that under certain conditions it may be profitable to carry growing animals thru the winter on roughages alone, even tho they lose slightly in weight, for on a return to good pasture, animals in spare but thrifty condition make exceedingly economical gains. However, the breeder of any class of stock who seeks to develop his animals toward an ideal must supply ample feed during the whole growth period.

QUESTIONS

1. How do the requirements for growing animals differ from those for maintaining mature animals?
2. Show by an example why the protein supply for growth must be not only ample in quantity but also of the right quality.

3. What is the effect of feeding rations deficient in mineral matter to growing animals?
4. Compare the economy with which young animals and mature ones use their food.
5. What is the object of fattening meat producing animals?
6. What is the composition of the gains during fattening?
7. From what materials may body fat be formed?
8. Discuss the food requirements of fattening animals?
9. What factors influence fattening?
10. Name the various farm animals in the order of their efficiency in making human food.
11. Describe the effects of feeding pigs corn alone.
12. What are the effects of supplying scanty rations to growing animals?

CHAPTER VI

PRODUCTION OF WORK, MILK, AND WOOL

I. Production of Work

It has long been known that muscular exertion or external body work greatly increases the amount of food material broken down in the body, but scientists have disagreed as to whether one or all of the nutrients—protein, carbohydrates, or fat—furnishes the energy.

The source of muscular energy.—By painstaking trials it was finally proved that all the organic nutrients, not only the carbohydrates and fats, but also the proteins and apparently the pentosans, may serve as sources of muscular work. Under normal conditions, the carbohydrates and fats of the food are first drawn upon, no more protein being broken down than during rest. Should these not furnish enough energy for the work, the body fat is next used. If this is still insufficient or is much diminished by continued work, then, as the last resort, the muscles or other protein tissues will be called upon for the needed energy.

Production of muscular energy.—We know that in doing work the muscles of the body contract, that is, become shorter and thicker. However, we do not yet understand in just what manner the energy of the nutrients is converted into the energy of muscular action, tho we do know some of the processes which take place in the working muscles.

In some marvelous manner the nutrients are suddenly broken down in the cells of the muscles, and part of the energy they contain is changed into mechanical work, while another part is set free as heat. In this change oxygen is taken up from the blood and carbon dioxid is given off, just as occurs when fuel is burned. The production of mechanical energy in the muscles is in a way similar to the production of power by a gasoline engine, where the fuel undergoes such a rapid breaking down that it becomes an explosion. As in the muscle, part of the energy of the fuel is turned into useful work and part is set free as heat. This latter part yields no useful work.

During rest, glycogen, or animal starch, is stored in the muscles, forming from 0.5 to 0.9 per ct. of the weight of well-nourished muscle when resting. A smaller amount of glucose is also stored in the muscles. Most of the energy produced in work is doubtless formed thru the oxidation of these two carbohydrates. Tho the supply in the body tissues at any one time is small, glucose is continuously being formed from the food nutrients or body tissues, to replace that used up during work.

The animal as a machine.—Numerous experiments have shown that animals at moderate work can convert into external work from 29 to 37 per ct. of the total energy expended. On the average, about one-third of the energy used by men or animals in muscular exertion is recovered as useful work. The rest takes the form of heat within the body, and is lost so far as the production of work is concerned. These figures do not take into account the energy lost in the excreta, that expended for digestion and assimilation, or that used in maintaining the body when at rest. Allowing for all of these, a horse doing a full day's work will turn about 8 per ct. or over of the gross energy of its feed into actual useful external work, such as hauling a load, without

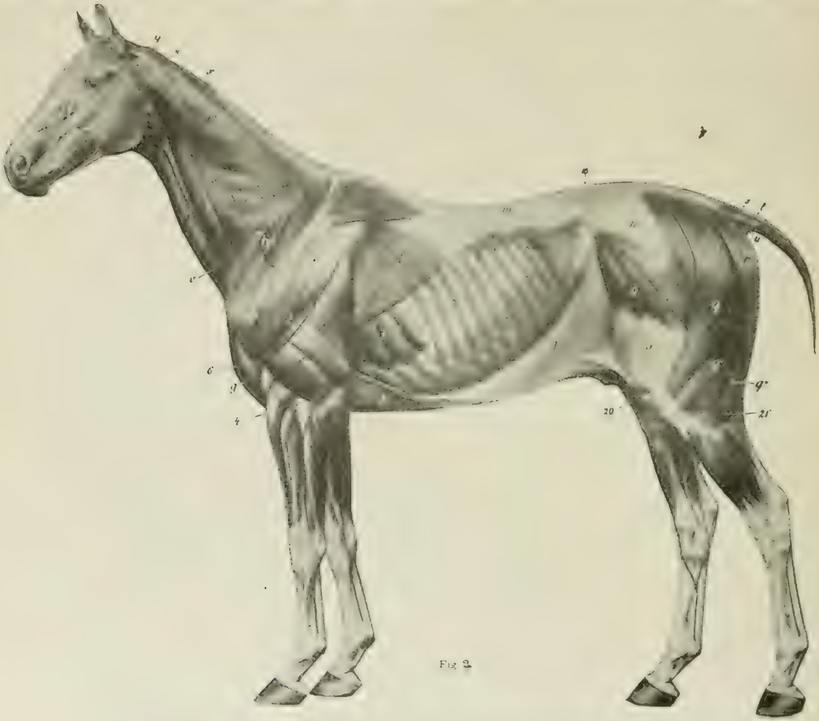

FIG. 23.—THE MUSCULAR SYSTEM OF THE HORSE

The work done yearly in this country by horses and mules is worth over $2,000,000,000. (From Ellenberger.)

counting the energy expended in the work of moving its own body. Recent tests have shown that on the average late models of farm tractors will convert just about the same percentage of the gross energy of the fuel into the work of draft.

Thus, as a mere machine, the animal compares favorably with the best modern tractors. The efficiency of the animal is especially striking when it is borne in mind that the tractor is supplied with purified fuel (kerosene or gasoline) from which much impurities and waste materials have been removed by distillation, while the horse must secure its energy from crude materials, including hay, of which only about half is actually digestible. Furthermore, he must digest this feed and himself separate out the useful from the waste material. Also, he must transport the fuel secured in his feed, and make all body repairs. Last but not least, he must maintain his body during the time he is not working, while when the tractor stops work, all expenditures of energy cease.

Factors influencing energy required for work.—The amount of energy required to produce a given amount of useful work depends upon many factors. Practice in doing a certain kind of work lessens the amount of energy expended. In one instance, training for two weeks decreased by over 20 per ct. the energy used by a man climbing a tower. On the other hand, fatigue greatly increases the energy required to do a given task. This is largely due to the fact that with increasing fatigue the muscles normally used, and which are thus most efficient in performing the given work, are put out of use. Then other less used muscles are called upon to a constantly increasing degree, and these cannot perform the work so economically. Increasing the speed at which the work is done also lessens the efficiency with which it is performed. This is because the work of the heart is increased, the body temperature rises, and much heat is lost by the evaporation of water thru the skin and lungs. This decreases the amount of work which a given quantity of feed will produce.

The part of the expended energy appearing in useful work varies with the build of the animal, the development of its muscles, and the structure of its limbs. For example, a lame horse may use nearly twice as much energy in traveling a certain distance as one with sound legs. An animal which is able to perform one kind of work most economically may have to expend undue energy at other kinds of work. Thus, horses bred for generations to the saddle can carry the rider with a smaller expenditure of energy than those whose breeding and form specially fit them for draft purposes.

Additional discussions of the factors influencing the production of work, as applied to horses, are given in Chapter XVIII.

II. Production of Milk

Secretion of milk.—Milk, the marvelous fluid designed by Nature for the nourishment of the young of all mammals, is secreted by special organs, called the mammary glands. Scientists disagree as to the exact process by which the milk is formed in the small, sac-like bodies, known as *alveoli,* in the udder. However, we do know that the blood, laden with nutrients, is brought by the capillaries of the udder to these alveoli. The nutrients then pass thru the walls of the capillaries into the alveoli. There, by one of Nature's wonderful processes, they are converted into milk, which differs entirely in composition from the blood whence it originates. The chief proteins of milk—casein and milk albumin—differ from all other proteins of the body, and the milk fat likewise has entirely different properties from the body fat of the same animal. Milk sugar, the carbohydrate of milk, is found nowhere else in the body. While the blood contains much more potassium than sodium, in milk the sodium predominates.

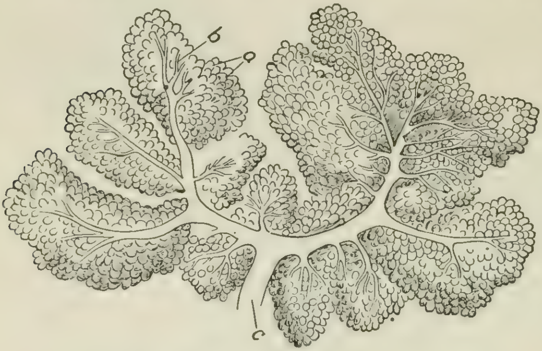

Fig. 24.—Mammary Gland of Cow

Small portion of gland, greatly magnified. A, alveoli, in which milk is secreted: b, small milk duct; c, larger milk duct. (After Klein.)

From the alveoli the milk passes into the network of milk ducts. In some animals the large milk ducts open directly on the surface of the teat, but in others, including the cow, they open into a small cavity, called the milk cistern, which is just above the teat. Most of the milk yielded at one milking is secreted during the milking process, for the udder has room for the storage of but a small part of the total product.

Tho the secretion of milk is involuntary and cannot be prevented by the animal, any more than can breathing or the circulation of the blood, the flow may be reduced by nervousness caused by fright, an unfamiliar attendant, or other unusual circumstance. The animal has considerable power to "hold up" the milk already secreted in the udder, by contracting the ring of muscle which partially separates the milk cistern from the teat, and similar muscles guarding the milk ducts.

Source of fat in milk.—For many years it was believed that the cow could form the fat of milk only from the fat in her food. This was disproved in an ingenious experiment at the New York (Geneva) Station.[1] For over 3 months a cow was fed on hay, cornmeal, and oats, from which the fat had been extracted by naphtha, as is done in one method of extracting the oil from flax seed. During this time the cow received only 5.7 lbs. digestible fat in her feed, but yielded 62.9 lbs. of fat in her milk. She was fatter at the end of the trial than at the beginning and so could not have converted her body fat into milk fat. From the amount of digestible protein in her feed, it was computed that not over 17 lbs. of the milk fat could possibly have come from the food protein. Thus, the larger part of the fat must have been formed from the carbohydrates of the feed.

Nutrients required for milk production.—A study of the nutrients the cow yields in her milk will aid in showing the kind and amount of nutrients her ration should furnish. A dairy cow of no unusual ability should yield annually 8,000 lbs. of milk of average quality. Taking the composition shown in a previous table (Page 64), we find that she will produce in her milk 272 lbs. of protein, 296 lbs. of fat, 392 lbs. of milk sugar, and 56 lbs. of mineral matter. This is 56 per ct. more protein, 30 per ct. more non-nitrogenous nutrients (fat and carbohydrates), and 19 per ct. more mineral matter than is contained in the entire body of a fat 2-year-old steer weighing 1,200 lbs.

Thus, each year the cow yields more protein and mineral matter than has been built into the body of the steer during its life. At the same time she may be storing considerable protein and mineral matter in the developing body of her unborn calf. It is therefore evident that, far different from the requirements of the mature horse at work or of a mature fattening animal, the cow needs a liberal supply of protein and mineral matter. Just as in the case of growing animals, this must not only be ample in quantity, but also of the proper kind or quality. Furthermore, the high-producing cow is working just as truly as the horse pulling a load, and hence needs a liberal supply of concentrates rich in net energy. Energy used up in the mastication, digestion, and assimilation of such feeds as straw takes the form of internal heat and is of no value for the formation of milk.

Since most of the scientific studies of the factors influencing the production of milk have been conducted with the dairy cow, the discussion of milk production by that animal is continued in Chapters XX and XXI. The requirements of the mare, ewe, and sow for the production of milk are also treated in the respective chapters of Part III.

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[1] Jordan and Jenter, N. Y. (Geneva) Bul. 132.

III. Wool Production

Composition of wool.—Aside from moisture and dirt, "wool" is made up of pure wool fiber and yolk, the latter including the suint and the wool fat. The wool fiber is practically pure protein, and is of the same chemical composition as ordinary hair, but differs in being covered with minute overlapping scales. The suint, chiefly composed of compounds of potassium with organic acids, comprises from 15 to over 50 per ct. of the unwashed fleece, being especially high in the Merino breed. As suint is soluble in water, most of it is removed by washing the unshorn sheep or the fleece, and less is present in the wool of sheep exposed to the weather. The fat, often incorrectly called yolk, is a complex mixture of fatty substances, insoluble in water, and may make up from 8 to 30 per ct. of the weight of a washed fleece.

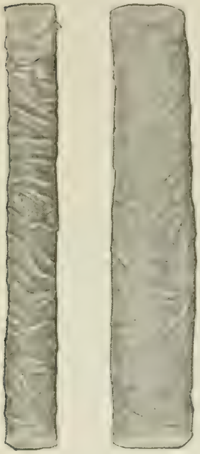

Fig. 25.—Wool Fibers

Appearance of fibers, greatly magnified, after dirt and yolk have been removed. Left, fiber of Merino wool; right, fiber of Down wool. Note the overlapping scales covering the fibers.

Requirements for wool production.—Owing to the large amount of protein stored by sheep in their fleeces, their rations should contain somewhat more protein than rations for cattle or swine at the same stage of maturity. This is taken into consideration in the various feeding standards for the different classes of animals. (See Appendix Tables IV and V.) With ewes which are either pregnant or suckling lambs, there is a double demand for food protein, which makes a liberal supply especially advisable.

When sheep are fed insufficient food to maintain their weight, the yield of wool is considerably diminished. On the other hand, the production of wool fiber and wool fat is practically no greater when a full-grown sheep receives a liberal fattening ration than when it is maintained in ordinary condition. Feeding lambs liberally produces a larger body and consequently a heavier fleece.

The strength of the wool fiber is dependent on the breed, the quality of the individual sheep, and the conditions under which they are raised. Conditions which check the growth of the wool, such as insufficient feed, undue exposure, or sickness, will produce a weak spot in the fiber. The feed and care for the flock should therefore be liberal and as uniform as possible.

QUESTIONS

1. What is the source of muscular energy?

2. Tell what is known about the way muscular energy is produced.

3. How do animals compare with engines in the efficiency with which they perform work?

4. Discuss the effects of speed, training, fatigue, and build of animal on the economy with which work is produced.

5. What is known about milk secretion?

6. How has it been shown that milk fat may be formed from the carbohydrates of the feed?

7. What are the food requirements of cows in milk?

8. Of what is wool composed?

9. Why should sheep be fed a larger proportion of protein than beef cattle or pigs?

10. In what manner does the feed influence the quantity and quality of wool?

CHAPTER VII

FEEDING STANDARDS—CALCULATING RATIONS

I. Early Feeding Standards

To guide the farmer in selecting rations for his stock, scientists have drawn up *feeding standards.* These are tables showing the amounts of each class of nutrients which, it is believed, should be provided for farm animals of the various ages and classes for the best results.

Early feeding standards.—At the beginning of the last century almost nothing was known about the chemistry of plants and animals, and the farmer gave his stock hay and grain without knowing what there was in this feed that nourished them. In 1859, when chemistry had thrown some light on the composition of feeds, Grouven, in Germany, proposed the first feeding standard for farm animals. This was, however, very imperfect, for it was based not on the amount of digestible nutrients required, but on the total crude protein, carbohydrates, and fat in feeding stuffs.

In 1864 Wolff, a German scientist, presented the first table of feeding standards based on the digestible nutrients contained in feeds. These set forth the amounts of digestible crude protein, carbohydrates, and fat required daily by the different classes of farm animals. The Wolff standards were brought to the attention of American farmers 10 years later and were further introduced by Armsby's "Manual of Cattle Feeding," which appeared in 1880. The value and importance of these standards were soon recognized and with their adoption came the first wide-spread effort toward the rational feeding of farm animals. In 1896 the Wolff standards were modified by Lehmann, as scientific trials had then thrown further light on stock feeding.

The numerous feeding experiments which have been carried on since the Wolff-Lehmann standards were presented have given us much more complete knowledge of the nutrients required by the various classes of farm animals than was then possessed. Therefore it is not advisable or economical at the present time to balance rations for the actual feeding of live stock according to these out-of-date standards. Instead, rations should be computed according to one of the modern standards presented later, which meet present conditions and are based upon the recent experiments in animal nutrition and stock feeding.

The Wolff-Lehmann standards are given in full in Appendix Table IV. From this the following examples are taken for purposes of study:

Digestible nutrients required daily per 1,000 lbs. live weight

Animal	Dry matter	Digestible nutrients			Nutritive ratio
		Crude protein	Carbohydrates	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.	
Ox, at rest	18	0.7	8.0	0.1	1:11.8
Fattening cattle, 1st period..	30	2.5	15.0	0.5	1: 6.5
Cow, yielding 22 lbs. milk...	29	2.5	13.0	0.5	1: 5.7
Horse, at medium work	24	2.0	11.0	0.6	1: 6.2

The table shows that according to the Wolff-Lehmann standards a 1,000-lb. ox at rest, neither gaining nor losing in weight, requires for 1 day's maintenance 18 lbs. of dry matter containing the following digestible nutrients: 0.7 lb. crude protein, 8.0 lbs. carbohydrates, and 0.1 lb. fat, with a nutritive ratio of 1:11.8. When the animal is growing, fattening, giving milk, or working, more nutrients must be supplied than for maintenance, as the table shows.

Careful experiments carried on since the Wolff-Lehmann standards were proposed have conclusively shown that dairy cows, work horses, and fattening cattle, sheep, and pigs all need considerably less crude protein than is recommended in these standards. As protein-rich feeds are usually the highest in price over much of our country, following these standards is usually very uneconomical. The recent experiments have been taken into consideration in drawing up the Morrison, or modified Wolff-Lehmann, standards which are discussed later in this chapter and given in Appendix Table V. As these are based upon the many feeding trials carried on in recent years, they furnish more accurate information on the requirements of farm animals than the Wolff-Lehmann standards.

Altho in the actual feeding of stock one of the more recent feeding standards described later in this chapter should be followed, both students and stockmen should, first of all, familiarize themselves with the Wolff-Lehmann standards because of their historical interest and because they are still sometimes used in computing rations for stock. After this, one is prepared for the study of the modern and more accurate standards discussed later.

II. CALCULATING RATIONS FOR FARM ANIMALS

General requirements of satisfactory rations.—The various feeding standards make recommendations only in regard to the amounts of dry matter, of the various nutrients, and, in the case of the Kellner and Armsby standards, of the net energy which the ration should supply. However, the following highly important factors should also be taken into account in computing rations for farm animals.

Suitability of feeds.—The feeds selected for any animal should be such that they will not injure its health or the quality of the product yielded. Feeds which are suited to one class of farm animals may not be adapted to others. Again, a given feed may give satisfactory results only when combined with certain other feeds. A few examples of such conditions are furnished in the following: Cottonseed meal in moderate amount is an excellent feed for cattle, sheep, and horses, yet it is frequently poisonous to pigs. Timothy hay, the standard roughage for horses, is unsatisfactory for dairy cows, and may cause serious trouble with sheep on account of its constipating effect. Feeding cows a heavy allowance of ground soybeans produces unduly soft butter, while an excess of cocoanut meal makes the butter too hard. It is often highly beneficial to add wheat bran or linseed meal to the ration because of their slightly laxative effect. When animals are

FIG. 26.—A "BALANCED" RATION WHICH IS UNSATISFACTORY AND EXPENSIVE

This ration of 18 lbs. timothy hay, 4 lbs. corn meal, 5 lbs. wheat bran, and 2.5 lbs. linseed meal, meets the standards for a 1,000-lb. dairy cow yielding 30 lbs. of 3.5 per ct. milk. However, the timothy hay is not palatable, and the ration is not only unsatisfactory but expensive. Cost 56 cents. (From Humphrey, Wisconsin Station.)

already receiving laxative feeds, such as corn silage, pasture grass, and legume hay, the use of bran or linseed meal may be unwise.

In computing rations one should therefore always learn whether the feeds under consideration are satisfactory for the given animals. The value and suitability of all important feeds for the various classes of stock are discussed in Part II of this book and more detailed information concerning their use with each kind of stock is given in Part III.

Bulkiness of ration.—We have already seen in Chapter IV that at least with the horse and with young ruminants the ration must contain some roughage to distend the digestive tract properly. Furthermore, for the best results, the proportion of concentrates and roughages in the ration should be regulated according to the kind and class of animal to be fed and the results desired. Cattle, sheep, and horses can be wintered satisfactorily on roughages alone, if of suitable quality, and even brood sows may be maintained chiefly on legume hay, when not suckling their young. On the other hand, a considerable part of the rations for growing and fattening animals and those at work or in milk should consist of concentrates. To fatten animals rapidly considerably more concentrates must be fed than when they are fattened more slowly. Similarly, horses at hard work should be given more grain and less roughage than those working but little.

FIG. 27.—A RATION WHICH IS FAIR, BUT LACKS SUCCULENCE

This ration of 20 lbs. red clover hay, 5 lbs. corn meal, and 4 lbs. oats furnishes only about as much digestible nutrients as the previous one, but will give better results, because the clover hay is more palatable to cows than timothy hay. Cost 48 cents. (From Humphrey, Wisconsin Station.)

The present feeding standards recognize these facts in the amount of dry matter they prescribe in the rations for the different classes of animals. Obviously, when the requirement of digestible nutrients or of net energy is high compared with the total amount of dry matter advised, the proportion of concentrates in the ration must be large to meet the standard. On the other hand, for the mere maintenance of animals the standards call for much less digestible nutrients or net energy compared with the amount of total dry matter.

In computing rations, the following will help to show the proportion of concentrates and roughages for the various classes of animals:

Mature idle horses and mature cattle and sheep being maintained at constant weight may be fed chiefly or entirely on roughage, unless it is of poor quality, when some grain must be used.

Horses at work should be given 2 to 2.5 lbs. of feed (dry roughages and concentrates combined) daily per 100 lbs. live weight, the concentrates ranging from about 0.7 to 1.4 lbs. per 100 lbs. live weight for horses at medium to hard work.

Dairy cows in milk will eat 2 lbs. of good quality dry roughage daily per 100 lbs. live weight. Silage may be substituted for dry roughage at the rate of 3 lbs. silage for 1 lb. dry roughage. A common rule is to feed 1 lb. legume hay and 3 lbs. silage daily per 100 lbs. live weight. Sufficient concentrates should be added to bring the nutrients up to the standard.

Fattening steers need 2.1 lbs. or more of concentrates and dry roughage (or the equivalent in silage) daily per 100 lbs. live weight, the allowance of concentrates ranging from less than 1 lb. to 1.7 lbs. or more, per 100 lbs. live weight, depending on the rate of gain desired and the kind of roughage.

Fattening lambs will consume about 1.4 lbs. of dry roughage daily when fed all the grain they will eat, and up to 2.3 lbs. or over when the grain allowance is restricted. Silage may replace a corresponding amount of dry matter in dry roughage.

Pigs can make but limited use of dry roughage, except in the case of brood sows not suckling young.

Mineral matter.—In the various feeding standards no statement is made as to the amount or kind of mineral matter required by the different classes of animals, the supposition being that a ration which provides the proper amount of protein and other nutrients will also furnish enough mineral matter. In some cases, especially with the pig, the mineral supply may be deficient in amount or unbalanced in character in rations which meet the ordinary standards. In computing rations the special requirements of the various classes of animals, as set forth in the preceding chapters, should therefore be kept in mind.

Palatability.—As has already been pointed out in Chapter IV, the palatability of the ration is an important factor in stimulating digestion and in inducing the animal to consume heavy rations. The wise feeder will utilize feeds of low palatability chiefly for such animals as are being merely maintained, and will feed growing and fattening ani mals, milch cows, and horses at hard work rations made up, for the most part at least, of well-liked feeds. Some concentrates, such as malt sprouts and dried distillers' grains, which may not be relished when fed alone, are entirely satisfactory if given in mixture with other better-liked feeds. Similarly, such roughages as straw and marsh hay, which are of low palatability, may be given in limited amount even to animals fed for production, a practice widely followed by European farmers. While the largest gains are made on rations composed entirely of exceedingly palatable feeds, it should be remembered that one of the chief functions of our domestic animals is to consume and convert into useful products materials which would otherwise be wasted.

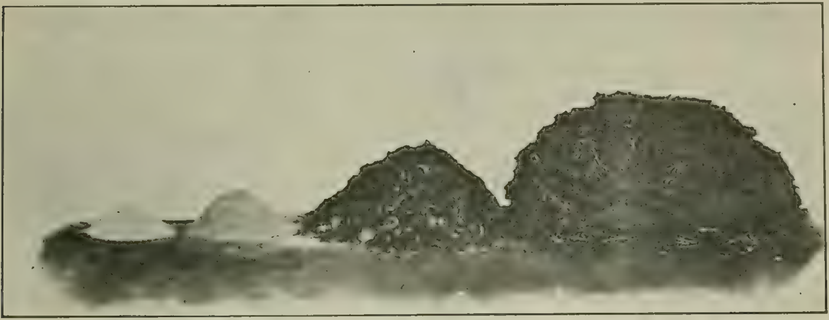

FIG. 28.—AN EXCELLENT AND ECONOMICAL RATION

This ration of 30 lbs. corn silage, 12 lbs. red clover hay, 3.5 lbs. corn meal, 2.5 lbs. wheat bran, and 1 lb. cottonseed meal furnishes no more nutrients, yet it is much superior to the two previous ones, for the feeds are all palatable and suitable for dairy cows, and the silage provides succulence. Cost 46 cents, nearly one-fifth less than the first ration. (From Humphrey, Wisconsin Station.)

Variety of feeds.—Skilled feeders usually believe that a ration containing several feeds will give better results than when a smaller number are employed, even tho the latter ration supplies the proper amount of protein, carbohydrates, and fat. From the discussions in the preceding chapters, in which it has been pointed out that the protein furnished by certain feeds is unbalanced in composition, it is evident that a larger variety of feeds may, by the law of chance, furnish a better balanced mixture of proteins than one or two feeds alone. It would therefore seem wise, in choosing supplements for a ration low in protein, to select those which will supply protein from different sources. For example, it is injudicious, if other supplements are equally available, to use corn by-products, such as corn gluten feed or gluten meal, in balancing the ration of pigs otherwise fed corn only.

With dairy cows, especially in the case of high-producing animals being forced on official test, skilled feeders place emphasis on having variety in the ration, tho this does not imply changes in the ration from day to day. Indeed, sudden changes in kinds of feed are to be avoided. At least for horses and fattening animals, a simple ration, providing it is well-balanced and palatable, is as satisfactory as one containing a large variety of feeds. For example, oats and timothy hay for the horse, and corn and skim milk for the fattening pig, furnish rations which can scarcely be improved from the standpoint of production and health, tho other combinations may perhaps be cheaper.

Cost of the ration.—Most important of all, for the farmer who depends on the profits from his stock for his income, is the cost of the ration. In devising cheap, yet efficient rations, lies a great opportunity for exercising foresight and business judgment on every farm where animals are fed. The wise farmer-feeder will consider the nutrient requirements of his animals in planning his crop rotations. Thru the use of grain from corn or the sorghums, combined with legume hay and such cheap succulence as corn or sorghum silage, it is possible in most sections of the country to go far toward solving the problem of providing a well-balanced, economical ration.

Feeding standards only approximate guides.—In Chapter III it has been shown that the composition of a given feeding stuff is not fixed, but is materially influenced by such factors as climate, stage of maturity when harvested, etc. Furthermore, individual animals differ in their ability to digest and utilize their feed. It should therefore be borne in mind that tables of digestible nutrients and likewise feeding standards are averages and approximations—something quite different from the multiplication table. While feeding standards are not to be followed blindly, they are exceedingly valuable guides when supplemented by business judgment and a practical knowledge of feeds and animals.

The allowance of protein set forth in the various standards is the minimum recommended by the scientists. Where protein-rich feeds are lower in price than those carbonaceous in character, as is alfalfa in the great alfalfa districts of the West and cottonseed meal in the cotton belt, it is often economical to furnish more protein than called for by the standards. Except with very young animals, it is, however, not advisable to feed rations having a nutritive ratio narrower than 1:4 or 1:4.5. Where protein-rich feeds are high in price it may be economical to feed a wider ration than advised even by the more modern standards, tho it is rarely wise to depart far from them.

Maintenance ration for steers.—Having discussed the general factors which should be considered in computing rations for farm animals, let us now calculate the feed required, according to the Wolff-Lehmann standard, to maintain a 1,000-lb. ox at rest in his stall when neither gaining nor losing in weight. Since mature animals can be maintained largely on roughages, let us see how nearly field-cured corn stover and oat straw will meet the requirements. As the standard calls for 18 lbs. of dry matter, we will first try quantities of these feeds which supply slightly less than this amount.

If for the trial ration it is decided to feed 10 lbs. of corn stover and 10 lbs. of oat straw for roughage, then, using the values for digestible nutrients given in Appendix Table III, the calculations for dry matter and digestible nutrients would be as given below:

	Corn stover, field-cured		Oat straw	
	In 100 pounds	In 10 pounds	In 100 pounds	In 10 pounds
Dry matter	59.0 ÷ 100 ×	10 = 5.90	88.5 ÷ 100 ×	10 = 8.85
Crude protein	1.4 ÷ 100 ×	10 = 0.14	1.0 ÷ 100 ×	10 = 0.10
Carbohydrates	31.1 ÷ 100 ×	10 = 3.11	42.6 ÷ 100 ×	10 = 4.26
Fat	0.6 ÷ 100 ×	10 = 0.06	0.9 ÷ 100 ×	10 = 0.09

Arranging these results in tabular form, we have:

First trial ration for maintaining 1,000-lb. ox at rest

Feeding stuffs	Dry matter	Digestible nutrients			Nutritive ratio
		Crude protein	Carbohydrates	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.	
Corn stover, 10 lbs.	5.90	0.14	3.11	0.06	.....
Oat straw, 10 lbs.	8.85	0.10	4.26	0.09	.....
First trial ration	14.75	0.24	7.37	0.15	1:32.2
Wolff-Lehmann standard	18.00	0.70	8.00	0.10	1:11.8
Excess or deficit	—3.25	—0.46	—0.63	+0.05	.....

This trial ration contains only about one-third the digestible crude protein called for and also falls below the standard in dry matter and carbohydrates. To improve it let us substitute 5 lbs. of clover hay, which is high in protein, for the same weight of corn stover, and add 0.5 lb. of protein-rich linseed meal. We then have:

Second trial ration for maintaining 1,000-lb. ox at rest

Feeding stuffs	Dry matter	Digestible nutrients			Nutritive ratio
		Crude protein	Carbohydrates	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.	
Clover hay, 5 lbs.	4.36	0.38	1.96	0.09	.....
Corn stover, 5 lbs.	2.95	0.07	1.56	0.03	.....
Oat straw, 10 lbs.	8.85	0.10	4.26	0.09	.....
Linseed meal, 0.5 lb.	0.45	0.15	0.16	0.03	.....
Second trial ration	16.61	0.70	7.94	0.24	1:12.1
Wolff-Lehmann standard	18.00	0.70	8.00	0.10	1:11.8
Excess or deficit	—1.39	0.0	—0.06	+0.14	.....

This ration closely approaches the standard. It falls below by more than 1 lb. of dry matter, but this deficiency is unimportant. The Wolff-Lehmann standards were devised to cover the common systems of feeding in Europe, where some straw or other low grade roughage is commonly included in rations for horses and ruminants. When only such high grade roughages as silage and legume hay are used, rations which supply enough digestible nutrients will fall below the standard in dry matter. If the ration furnishes sufficient bulk to distend the digestive tract properly, no further attention need be paid to such a deficit. The excess of fat in this case will more than make up the trifling deficit of carbohydrates, for fat has 2.25 times the heat value of carbohydrates. The nutritive ratio of this ration is 1:12.1, which is close to the standard. American rations will usually furnish an excess of fat over the standard, in which case the carbohydrates may fall somewhat below, as an offset.

III. The Armsby Net Energy Values and Feeding Standards

In Chapter III it has been pointed out that the total quantity of digestible nutrients in a feeding stuff is not theoretically the true measure of its feeding value, as is assumed in the Wolff-Lehmann feeding standards. Experiments by Kellner and Zuntz in Germany and by Armsby in this country have shown that to find the true net value of a feed for production it is necessary to deduct from the total energy furnished by the digestible nutrients in the feed, the energy lost in the urine and the gases produced in the digestive tract and that spent in the work of mastication, digestion, and assimilation.

Net energy values.—Kellner was the first to prepare tables showing the net energy values of feeding stuffs. In these he took 1 lb. of digestible starch as his unit and expressed the net energy values of different feeds in terms of "starch values." He then drew up feeding standards based on these starch values, which are now quite largely used in Germany.[1] We will not discuss these in detail, but will consider instead Armsby's net energy values and feeding standards, which are chiefly used in this country by those desiring to compute rations according to the net energy system.

From his data and that of Kellner, Armsby has prepared a table, based on the analyses in the Appendix Tables of *Feeds and Feeding,* which shows the net energy values of the leading American feeds. This table, part of which is given as Appendix Table VII of this book, shows also the total dry matter in each feed and the digestible true protein (not digestible crude protein).

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[1] For Kellner's starch values and feeding standards see his books, *Ernährung der Land. Nutztiere* and *Futterungslehre,* and the English translation of the latter book, *The Scientific Feeding of Animals.*

Of all the cereals listed, it is shown that rye has the highest net energy value, 93.71 therms per 100 lbs. Due chiefly to the large amount of fiber contained in the hulls, the net energy value of oats is only 67.56 therms per 100 lbs. The roughages, which are high in fiber and thus require much energy in mastication and digestion, furnish much less net energy than the concentrates. Wheat straw is the lowest in net energy of the dry roughages listed, having a value of only 7.22 therms per 100 lbs.

The Armsby feeding standards.—Armsby has recently drawn up revised feeding standards, based on his net energy values, for maintaining horses, cattle, sheep, and swine, for growing cattle, sheep, and swine, for work horses, for milk cows, and for fattening stock. These are given in Appendix Table VIII, with the exception of the standards for milk cows, which are given on page 100. In these standards, it will be noted, the requirements of the various classes of animals are expressed in terms of digestible true protein (not digestible crude protein) and of therms of net energy.

In the Wolff-Lehmann standards it is assumed that the requirements for maintaining animals depend on the live weight, the standards giving the nutrients required per 1,000 lbs. live weight. Armsby, however, has computed the maintenance requirements separately for animals of various weights. (See Page 52.) It will be noted that for maintaining a 500-lb. horse 2.58 therms of net energy are required, while for a 1,000-lb. horse only 4.10 therms of net energy are needed. Tho the second horse weighs twice as much, Armsby believes it does not take twice as much feed to maintain him.

Bull and Emmet of the Illinois Station [2] have made a comprehensive study of the American investigations in fattening lambs, and have presented feeding standards based thereon. These standards are expressed like the Armsby standards in therms of net energy, but give the amount of digestible crude protein required, instead of the amount of digestible true protein. For example, in these standards it is recommended that lambs weighing 50 to 70 lbs. be fed 3.1 to 3.8 lbs. digestible crude protein and 17 to 19 therms daily per 1,000 lbs. live weight.

Ration for maintaining the steer.—To illustrate the method of using the Armsby standards and table of net energy values, let us compute a ration for maintaining a mature steer weighing 1,000 lbs., when neither gaining nor losing weight, assuming that there are available

[2] Ill. Bul. 166.

corn stover, oat straw, dent corn, and cottonseed meal. According to the standard, an animal of this weight requires 0.5 lb. digestible protein and 6.0 therms of net energy. As corn stover and oat straw are much cheaper than the concentrates, let us first see how nearly a ration of these roughages alone will meet the requirements. Suppose that we select for a trial ration 8 lbs. of oat straw and 10 lbs. of corn stover. The calculations will then be as follows:

Calculations for trial ration for maintaining 1,000-lb. steer

	Corn stover			Oat straw	
	In 100 lbs.	In 10 lbs.		In 100 lbs.	In 8 lbs.
Dry matter	...81.0 ÷ 100 × 10 =	8.10	Dry matter	.....88.5 ÷ 100 × 8 =	7.08
Dig. protein	... 1.6 ÷ 100 × 10 =	0.16	Dig. protein	.... 0.8 ÷ 100 × 8 =	0.06
Net energy	...31.62 ÷ 100 × 10 =	3.16	Net energy	....34.81 ÷ 100 × 8 =	2.78

First trial ration for maintaining 1,000-lb. steer

Feeding stuffs	Total dry matter	Digestible protein	Net energy value
	Lbs.	Lbs.	Therms
Corn stover, 10 lbs.	8.10	0.16	3.16
Oat straw, 8 lbs.	7.08	0.06	2.78
First trial ration	15.18	0.22	5.94
Standard requirement ...	....	0.50	6.00
Excess or deficit........	....	—0.28	—0.06

This ration furnishes enough net energy but is deficient in digestible protein. Corn, which is high in net energy but low in protein, will not improve the ration, while cottonseed meal, which is rich in protein, will make up the deficiency. Let us therefore substitute 1 lb. of choice cottonseed meal for 2 lbs. of oat straw. We then have:

Second trial ration for maintaining 1,000-lb. steer

Feeding stuffs	Total dry matter	Digestible protein	Net energy value
	Lbs.	Lbs.	Therms
Corn stover, 10 lbs.......	8.10	0.16	3.16
Oat straw, 6 lbs.	5.31	0.05	2.09
Cottonseed meal, 1.0 lb....	0.92	0.35	0.93
Second trial ration......	14.33	0.56	6.18
Standard requirement ..	....	.50	6.00
Excess or deficit........	....	+0.06	+0.18

This ration agrees closely with the standard in digestible protein and net energy value. Thus, according to the Armsby standard, a satisfactory ration for maintaining a 1,000-lb. steer may be composed of 10 lbs. corn stover, 6 lbs. oat straw and 1 lb. choice cottonseed meal.

Discussion of the net energy systems.—Determining the net energy values of feeds is an important advance in our knowledge of their values for productive purposes. Unfortunately, owing to the immense amount of labor required for each determination, data of this kind can be secured but slowly. In his years of study Kellner determined the starch values for only about a dozen feeds and in 14 years Armsby has been able to study only 10 feeds, several determinations of course having been made upon each. While the results for these few feeds are helpful in estimating the probable net energy values of other feeds not yet tested, such computed results are more or less rough estimates of the true net energy values.

Moreover, both Kellner and Armsby have practically worked only with the steer, and the extent to which the values thus secured apply to other classes of animals is a question. It has been shown that they are too low for the dairy cow and too high for steers near the close of the fattening period. With cattle upwards of 17 per ct. of the heat value of the digested food is lost thru the fermentations which take place in the digestive tract, especially the paunch. On the other hand, there is but a small loss of this kind with horses or pigs. Hence, net energy values found in trials with steers are more or less inaccurate for horses and pigs. As Kellner himself states, in spite of the vast amount of study given to the subject, there are still many gaps in our knowledge of the actual net energy values of the different feeding stuffs. While the present values are not exact measures of the value of feeds for all classes of animals, they are, however, most helpful in teaching great principles in the feeding of live stock.

IV. The Scandinavian Feed-Unit System

A system of feed equivalents, based mainly on extensive experiments with milch cows at the Copenhagen Station, has been adopted in Denmark and other Scandinavian countries, especially by cow-testing associations, for measuring the relative efficiency of milk production by different herds and individual cows. The system is also occasionally used with pigs, but rarely for other stock. It has been exceedingly useful in co-operative efforts to improve dairy cattle and their feeding—lines in which the Scandinavian farmers are leaders.

The feed unit.—In the feed-unit system the value of the different feeds is compared with the value of 1 lb. of standard grain feed, such as corn and barley, which are taken as the unit of value. The amounts of the various feeds required to equal 1 feed unit are given in Appendix Table VI.

The table shows that corn, wheat, rye, barley, hominy feed, the dry matter in roots, etc., are all considered to have about the same value for the dairy cow, 1 lb. equaling 1 feed unit. On this basis it requires 1.1 lbs. of wheat bran or oats, or 1.5 to 3 lbs. of alfalfa or clover hay to equal 1 feed unit. Cottonseed meal, linseed meal, dried distillers' grains, gluten feed, and soybeans are rated at a higher value than the same weight of corn or wheat, less than a pound of these concentrates being required for a feed unit.

The feed-unit values are not true expressions of net energy, for in this system feeds rich in protein are given a higher value than feeds low in protein which furnish the same amount of net energy. For example, in the feed-unit system, only 0.9 lb. of linseed meal, gluten feed, or distillers' grains are required to equal 1 feed unit. Yet the real net energy of these feeds is lower than that of corn. Again, the energy value of timothy hay is higher than that of clover or alfalfa hay, but in the feed-unit system timothy hay is rated 50 per ct. below the legume hays. When added to rations too low in protein, feeds rich in protein will have a higher value than those supplying an equal amount of net energy but which are low in protein. But as has been pointed out in Chapters IV and V, when the ration already contains plenty of protein, any additional amount will have no higher value for the formation of fat or the production of milk or work than an equal amount of net energy supplied by carbohydrates or fat.

The value of any feed to the stockman depends on the other feeds which he has at hand. When he has an abundance of cheap carbonaceous feeds, protein-rich feeds to balance the ration will be worth much more to him than an additional supply of carbonaceous feeds. On the other hand, in the West with its cheap alfalfa hay and in the South with its low-priced cottonseed meal, feeds low in protein and rich in carbohydrates may often be worth more than those rich in protein. The feed-unit system has been developed in a comparatively small region, where similar crops are grown on the different farms and the price of purchased feeds is quite uniform thruout the entire district, hence this difficulty has not arisen there. No arbitrary values for feeding stuffs, expressed in terms of feed units, money, or other fixed units, can be devised which will hold good under such widely differing conditions as are found in the various sections of the United States.

Measuring economy of cows in feed units.—The chief value of the feed unit system for dairymen is for comparing the efficiency with which individual cows and different herds produce milk and butter fat. The method of making such comparisons is as follows:

If during a month a cow has consumed 240 lbs. of hay, 750 lbs. of silage, 60 lbs. each of barley and ground corn, and 90 lbs. of linseed oil meal, the calculation based on the valuation table would be as follows:

Feed consumed		Lbs. for 1 unit		Feed units
240 lbs. hay	÷	2.5	=	96
750 lbs. silage	÷	6.0	=	125
120 lbs. corn and barley	÷	1.0	=	120
90 lbs. oil meal	÷	0.9	=	100
Total feed units			=	441

It is shown that the cow consumed 441 feed units during the month. If in that time she yielded 850 lbs. of milk, containing 30.6 lbs. of fat, each 100 feed units produced $\frac{850}{4.41} = 193$ lbs. of milk, containing $\frac{30.6}{4.41} =$ 6.9 lbs. butter fat. If the fat brought 30 cents per pound, 100 feed units would return 6.9 × \$0.30 = \$2.07. Similar comparisons of the economy of production of various cows and herds may be made on the basis of the therms of net energy or the pounds of total digestible nutrients consumed.[3]

V. American Standards for Dairy Cows

The Haecker standard.—As the result of long years of study at the Minnesota Station,[4] Haecker has made an important advance in the computing of rations for the dairy cow. He has shown that the nutrients required for her nourishment should vary not only with the quantity of milk yielded, as is taught in the standards previously discussed, but also with the quality of the product. The allowance of crude protein recommended is also considerably lower than that set forth in the Wolff-Lehmann standard. In his standard Haecker first sets down the total digestible nutrients daily required to maintain the 1,000-lb. cow, independent of the milk she produces, as follows: Crude protein 0.7 lb., carbohydrates 7.0 lbs., and fat 0.1 lb. For each 100 lbs. live weight the cow may exceed or fall below the 1,000-lb. standard there is added or subtracted one-tenth of the standard ration.

To this maintenance provision the further allowance set forth in the table is added.

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[3] Hansson has proposed the following feeding standard for dairy cows according to the feed unit system. This is not of much interest to American dairymen, however, for it is less accurate than the standards of Haecker, Savage, or Eckles, which are described later, and which recognize the important fact that the feed requirements of dairy cows depend not only on the quantity but also on the richness of their milk.

For maintenance, feed 0.65 lb. digestible protein and 6.6 feed units daily per 1,000 lbs. live weight.

For each pound of milk produced add to the maintenance requirement 0.045 to 0.05 lb. digestible protein and 0.33 feed unit.

[4] Minn. Buls. 71, 79, 130, 140.

Haecker's feeding standard for the dairy cow

	Daily allowance of digestible nutrients		
	Crude protein	Carbohydrates	Fat
	Lbs.	Lbs.	Lbs.
For support of the 1,000-lb. cow	0.700	7.00	0.100
To the allowance for support add:			
For each lb. of 3.0 per ct. milk	0.047	0.20	0.017
For each lb. of 3.5 per ct. milk	0.049	0.22	0.019
For each lb. of 4.0 per ct. milk	0.054	0.24	0.021
For each lb. of 4.5 per ct. milk	0.057	0.26	0.023
For each lb. of 5.0 per ct. milk	0.060	0.28	0.024
For each lb. of 5.5 per ct. milk	0.064	0.30	0.026
For each lb. of 6.0 per ct. milk	0.067	0.32	0.028
For each lb. of 6.5 per ct. milk	0.072	0.34	0.029
For each lb. of 7.0 per ct. milk	0.074	0.36	0.031

To illustrate the use of the table there are computed below the requirements of a 1,100-lb. cow producing 25 lbs. of 4 per ct. milk daily:

Digestible nutrients required daily by the above cow

	Crude protein	Carbohydrates	Fat
	Lbs.	Lbs.	Lbs.
For maintenance	0.77	7.70	0.11
For 25 lbs. of 4 per ct. milk	1.35	6.00	0.52
Total	2.12	13.70	0.63

In the above there is first set down the maintenance allowance for the 1,000-lb. cow, increased by one-tenth because this cow weighs 100 lbs. more than the standard; this is 0.77 lb. crude protein, 7.7 lbs. carbohydrates, and 0.11 lb. fat, all digestible. The previous table shows the daily nutrient allowance for each pound of 4 per ct. milk to be 0.054 lb. crude protein, 0.24 lb. carbohydrates, and 0.021 lb. fat, all digestible. Since this cow is yielding 25 lbs. of milk daily, the foregoing numbers multiplied by 25 are placed in the second line of the table. Adding these nutrients to those for maintenance, we have 2.12 lbs. of protein, 13.7 lbs. of carbohydrates, and 0.63 lb. of fat as the quantity of digestible nutrients required daily to nourish a 1,100-lb. cow properly when giving 25 lbs. of 4 per ct. milk daily.

The Woll-Humphrey standard.—At the Wisconsin Station Woll and Humphrey prepared convenient tables showing the feed requirements of cows of different weights and producing various amounts of butter fat per day. To simplify the computation of rations, in these tables the requirements are stated in terms of dry matter, digestible crude protein, and total digestible nutrients, the latter term including the digestible protein, the digestible carbohydrates, and the digestible fat × 2.25. This simplification agrees with the uses made of the different nutrients in the animal body, for, as we have already learned, carbohydrates and fat in general perform the same functions in the body. Likewise, after there has been supplied the minimum amount of protein needed for the repair of body tissues and the formation of milk protein, any additional amount serves the same purposes as do the carbohydrates and fat. The requirements of a 1,000-lb. cow, according to this system,[5] are shown in the following table. The allowance for maintenance is the same as in the Haecker standard:

Woll-Humphrey standard for 1,000-lb. dairy cow

	Dry matter Lbs.	Digestible crude protein Lbs.	Total digestible nutrients Lbs.
Dry cow	12.5	0.70	7.9
Cow yielding 1.0 lb. fat per day	22.3	2.02	15.4
Cow yielding 1.5 lbs. fat per day	27.3	2.86	19.2
Cow yielding 2.0 lbs. fat per day	30.9	3.42	23.0

This system of expressing the requirements of dairy cows has been found convenient in practice. It is not strictly accurate, however, when applied to milks varying widely in the percentage of fat contained. Haecker's table places the requirements for a pound of butter fat in rich milk considerably lower than for a pound in milk low in fat. For example, for 100 lbs. of 3 per ct. milk there are required 4.7 lbs. protein, 20.0 lbs. carbohydrates, and 1.7 lbs. fat, while for 50 lbs. of 6 per ct. milk, containing the same amount of fat, only 3.3 lbs. protein, 16.0 lbs. carbohydrates, and 1.4 lbs. fat are required. This is due to the fact that, tho the 6 per ct. milk contains twice as much fat as the 3 per ct. milk, it is not twice as rich in sugar and protein.

The Savage standard.—From trials at the New York (Cornell) Station[6] Savage concludes that for maximum production the nutritive ratio of rations for dairy cows should not be wider than 1:6. He has accordingly modified the Haecker standard by increasing the protein requirement per pound of milk from 18 to 20 per ct. His standard is also simplified by being stated in terms of dry matter, digestible crude protein, and total digestible nutrients (or as Savage terms it "total nutriment"), in the same manner as in the Woll-Humphrey standard. The requirements according to this standard are shown in the next table.

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[5] Table as revised by Humphrey, unpublished data.

[6] N. Y. (Cornell) Bul. 323.

The Eckles and the Armsby standards.—From experiments at the Missouri Station [7] and from the work of Savage and Armsby, Eckles drew up standards according to the Armsby system, showing the requirements of cows producing milk containing various percentages of fat. More recently Armsby himself has presented feeding standards for dairy cows, based on the net energy system. These are included in the next table.

Comparison of standards for dairy cows.—In the following table the Haecker, Savage, and Armsby standards are brought together for comparison. Haecker's figures have been converted into total digestible nutrients as in the Savage standard.

Feeding standards for dairy cows compared

	Haecker standard		Savage standard		Armsby standard	
	Diges'ble crude protein	Total digestible nutrients	Diges'ble crude protein	Total digestible nutrients	Diges'ble true protein	Net energy
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Therms
For maintenance of 1,000-lb. cow	0.700	7.925	0.700	7,925	0.500	6.00
To allowance for maintenance add:						
For each lb. of 2.5 per ct. milk.	0.045	0.254	0.053	0.257	0.041	0.190
For each lb. of 3.0 per ct. milk.	0.047	0.284	0.057	0.287	0.043	0.214
For each lb. of 3.5 per ct. milk.	0.049	0.313	0.061	0.319	0.045	0.238
For each lb. of 4.0 per ct. milk.	0.054	0.343	0.065	0.350	0.049	0.265
For each lb. of 4.5 per ct. milk.	0.057	0.372	0.069	0.379	0.052	0.291
For each lb. of 5.0 per ct. milk.	0.060	0.398	0.073	0.405	0.055	0.315
For each lb. of 5.5 per ct. milk.	0.064	0.424	0.077	0.431	0.058	0.338
For each lb. of 6.0 per ct. milk.	0.067	0.451	0.081	0.457	0.061	0.361
For each lb. of 6.5 per ct. milk.	0.072	0.480	0.085	0.484	0.064	0.385
For each lb. of 7.0 per ct. milk.	0.074	0.502	0.089	0.508	0.068	0.408

The Haecker and Savage standards agree in the requirements for maintenance. Savage's digestible crude-protein requirement for production is higher in each case, as already pointed out. In total digestible nutrients he agrees quite closely with Haecker. As Armsby's standard is expressed in digestible true protein (not crude protein) and therms, it cannot be directly compared with the others. By computing the amount of true protein and crude protein in typical good dairy rations, it will be found that if Armsby's figures were changed into crude protein they would be fully as high as the recommendations of Savage. Similar comparisons show that the Armsby standard calls for less total nutrients and hence requires less concentrates than the other standards. An experiment by Morrison, Humphrey, and Putney at the Wisconsin Station shows that cows fed enough concentrates to meet the requirements of the Savage standards produced slightly more milk and butter fat than when fed enough to meet the Armsby standards. However with feeds at 1918 prices milk and butter fat were produced at slightly lower cost on the

Armsby ration. From this we may conclude that when high production is desired, it is necessary to feed as much concentrates as called for in the Savage or Haecker standards, but when the object is economy of production, it is best to feed slightly less concentrates if they are high priced compared with roughages. Likewise, when protein-rich feeds are high in price it may be most economical to feed only as much protein as recommended in the Haecker standards. These facts are taken into consideration in the Morrison standards. The skilled dairyman will not compute a ration for each of his cows, but will follow one of the general rules for feeding given on Page 260.

VI. MORRISON FEEDING STANDARDS

Methods of computing rations compared.—In this chapter it has been pointed out that valuing feeds for productive purposes on the basis of their net energy content, is theoretically more accurate than the Wolff-Lehmann method of comparing them in terms of the digestible nutrients they furnish. Unfortunately, the net-energy values have been determined for but a few feeds, and with these only for the fattening steer. For other feeds and other classes of animals, the values which may be computed are but approximations. On the other hand, during the last half-century scores of thousands of analyses of feeding stuffs have been made, as shown in Appendix Table I, and large numbers of digestion experiments have been conducted in which the coefficients of digestibility have been determined, as given in Appendix Table II. Thus, the values for digestible nutrients in the various feeding-stuffs, given in Appendix Table III, rest on a reasonably secure basis, tho we must remember that different kinds of animals digest somewhat different percentages of feeds, especially of roughages.

The value of a concentrate and of a roughage for productive purposes cannot be compared on the basis of the digestible nutrients each furnishes, for in the roughage, containing more fiber, a larger part of the energy in the digested nutrients is used up in the non-productive work of mastication, digestion, and assimilation. In the ordinary rations for each class of animals, concentrates and roughages are, however, usually fed in about the same proportions. This tends to lessen any error due to inaccuracy in computing rations according to the Wolff-Lehmann method.

Furthermore, in this method a definite amount of dry matter is prescribed. If a ration contains sufficient digestible nutrients to meet the Wolff-Lehmann standards, but carries too much dry matter, obviously too much roughage or concentrates too high in fiber have been used, and the net-energy value will consequently be too low. On the other hand, if the content of digestible nutrients satisfies the standard, while the ration does not contain the dry matter called for, it shows that feeds more concentrated in character than necessary have been used. In this case some roughage or feeds higher in fiber may be substituted till the dry-matter content is brought up to the standard.

Necessity for modifying the Wolff-Lehmann standards.—It has already been shown in this chapter that the original Wolff-Lehmann standards are inaccurate in many respects and do not meet present-day American conditions. We know, for example, that the allowance of digestible crude protein advised is higher than is needed by fattening animals, dairy cows, and work horses. Yet, until the standards described below were prepared, the original Wolff-Lehmann standards were more commonly used in this country, except perhaps for dairy cows, than any other system for balancing rations. Indeed, the authors have recently found feeders, annually fattening hundreds and even thousands of animals, who were balancing rations according to the original Wolff-Lehmann standards by the addition of entirely unnecessary amounts of high-priced protein-rich concentrates.

Morrison feeding standards.—Appreciating the vital need for up-to-date standards which meet American conditions, there have been combined into the Morrison or modified Wolff-Lehmann feeding standards what appear to be the best guides we have at present in balancing rations for the different classes of farm animals. To make the computations as easy as possible, the standards, which are given in detail in Appendix Table V, are expressed simply in terms of total dry matter, digestible crude protein, and total digestible nutrients. Realizing that feeding standards are but approximations, in most cases minimum and maximum figures are given for dry matter, digestible crude protein, and total digestible nutrients. Since progressive feeders thruout the country now appreciate the significance of the nutritive ratio of a ration, the approximate upper and lower advisable limits of nutritive ratios for the different classes have been stated. To correspond with these standards, Appendix Table III contains a column showing the total digestible nutrients furnished in 100 lbs. of each feed. Likewise, so that one may see at a glance which feeds are high and which are low in protein, compared with carbohydrates and fat, the nutritive ratio for each feed has been computed and is given in the table. With these aids it is hoped that these standards may be of real assistance to students and feeders who desire to compute rations substantially in accordance with the Wolff-Lehmann method, while recognizing the results of the later investigations in animal feeding.

Ration for a work horse.—To illustrate the manner of using the Morrison standards, let us compute a ration for a 1,400-lb. horse at hard work. The standard for horses at hard work calls for 18.0–22.0 lbs. of dry matter, 1.5–1.8 lbs. digestible crude protein, and 13.0–15.0 lbs. total digestible nutrients per 1,000 lbs. live weight. (See Appendix Table V.) The nutritive ratio should not be wider than 1.7.6–1.8.1. Multiplying the requirements for 1,000 lbs. by 1.4, we find that this 1,400-lb. horse will require 25.2–30.8 lbs. dry matter, 2.10–2.52 lbs. digestible crude protein, and 18.2–2.10 lbs. total digestible nutrients.

Let us suppose that this is to be a corn-belt ration and that dent corn is the cheapest grain available. For roughage we have plenty of timothy hay and good, bright, clover hay. According to the rule on Page 88, work horses should be given 2 to 2.5 lbs. of feed (roughages and concentrates combined) daily per 100 lbs. live weight. Horses at medium to hard work will need 0.7 to 1.4 lbs. concentrates daily per 100 lbs. live weight. As it is costly to feed more grain than necessary, we will take for a trial ration the minimum amount of corn (0.7 lb. × 14 = 9.8 lbs., or about 10 lbs.) and enough hay to make 2 lbs. total feed for each 100 lbs. the horse weighs, or 18 lbs. of hay.

First trial ration for 1,400-lb. horse at hard work

Feeding stuffs	Dry matter	Dig. crude protein	Total dig. nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	
Dent corn, 10 lbs.	8.95	0.75	8.57	
Timothy hay, 18 lbs.	15.91	0.54	8.73	
Total	24.86	1.29	17.30	1:12.4

This ration furnishes nearly as much total digestible nutrients as is called for in the standard, but falls far short in crude protein, having the very wide ratio of 1:12.4. We can bring the crude protein up to the standard by substituting protein-rich concentrates for a considerable part of the corn, but this will add to the expense, for we have assumed that corn is the cheapest grain available. Tho timothy hay is more commonly fed to horses than any other in the northeastern United States, good, bright, clover hay, which is rich in protein, is practically as satisfactory for work horses. Let us then see how near we will come to meeting the standard if we substitute clover hay for half the timothy hay and add 2 lbs. of corn to bring the total digestible nutrients up to the standard. Arranging the results as before, we will have:

Second trial ration for 1,400-lb. horse at hard work

Feeding stuffs	Dry matter	Dig. crude protein	Total dig. nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	
Timothy hay, 9 lbs.	7.96	0.27	4.36	
Clover hay, 9 lbs.	7.84	0.68	4.58	
Dent corn, 12 lbs.	10.74	0.90	10.28	
Total	26.54	1.85	19.22	1:9.4

This ration is still somewhat below the standard in digestible crude protein, but it will supply sufficient total digestible nutrients unless the horse is working extremely hard. To furnish the necessary crude protein we could substitute clover hay for the rest of the timothy hay, and then have as the ration, 18 lbs. clover hay and 12 lbs. dent corn. This would supply 2.27 lbs. digestible protein and 19.44 lbs. total digestible nutrients, and would have a nutritive ratio of 1:7 6. This ration would fully meet the standard and would be economical under most conditions.

We could also balance the ration by substituting 1 lb. of choice cottonseed meal for 1 lb. of dent corn, as is shown in the following table.

Third trial ration for 1,400-lb. horse at hard work

Feeding stuffs	Dry matter	Dig. crude protein	Total dig. nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	
Timothy hay, 9 lbs.	7.96	0.27	4.36	
Clover hay, 9 lbs.	7.84	0.68	4.58	
Dent corn, 11 lbs.	9.84	0.82	9.43	
Cottonseed meal, choice, 1 lb.	0.92	0.37	0.78	
Total	26.56	2.14	19.15	1:7.9

This ration meets the standard in all particulars and will give good results in practice. It should not be fed blindly, however, for some horses are hard and others easy keepers. Therefore, if the horse loses weight on this ration, increase the allowance of corn gradually. On the other hand, if he is an easy keeper and becomes too fat, cut down the amount of corn. Other protein-rich feeds, such as wheat bran, dried brewers' grains or linseed meal, could be used just as satisfactorily as cottonseed meal in balancing the ration, the choice depending on the prices of the various feeds available.

Guides in computing economical rations.—Before attempting to compute rations for any class of stock, it is important to study carefully the explanations and general hints on Pages 86–90 and in the next chapter. It is impossible to compute satisfactory and economical rations if reliance is placed only on the mathematical recommendations of the feeding standards. As is explained on these pages, other factors are just as important as the amounts of digestible protein and of total digestible nutrients. The special rules and hints on feeding each class of stock, which will be found on the following pages, should also be consulted:

Dairy cows, 258–62.
Fattening steers, 292, 295–6.
Beef breeding cows, 300–1
Horses, 227–8, 229–30.
Brood mares, 230–1.
Growing colts, 232–4.
Fattening lambs, 330–3.
Breeding ewes, 326–8.
Growing, fattening pigs, 348, 358–60.
Brood sows, 354–6.
Poultry, 380, 384–6, 394–5.

QUESTIONS

1. What are the essentials of a satisfactory ration?

2. Compute a ration for a 1,400-lb. horse at medium work according to the Wolff-Lehmann standard. In this and the following problems use feeds available in your local district and find the cost of the ration at local prices.

3. Wherein do the Armsby and Kellner standards differ from the Wolff-Lehmann standards?

4. Compute a ration for maintaining a 1,200-lb. steer according to the Armsby standard.

5. During a month a cow produced 920 lbs. of milk containing 3.8 per ct. butter fat. She ate 360 lbs. of alfalfa hay, 900 lbs. corn silage, 120 lbs. corn meal, and 60 lbs. wheat bran. How much milk and how much butter fat did she yield per 100 feed units?

6. What are the distinguishing features of the Haecker standard for dairy cows?

7. Wherein does the Woll-Humphrey standard differ from the Haecker standard?

8. Compare the amounts of protein and total digestible nutrients recommended in the Savage and Armsby standards with the Haecker standard.

9. How do the Morrison or modified Wolff-Lehmann standards differ from the original Wolff-Lehmann standards?

10. Compute a ration for a 1,400-horse at medium work according to the Modified Wolff-Lehmann standard. How does this ration differ from the one given in the book for the horse at hard work?

11. Compute rations for fattening 2-year-old steers on full feed (a) for the first 50 days when the steers average 1,100 lbs. in weight, (b) for the second 50 days when they average 1,210 lbs., and (c) for the last 50 days when they average 1,320 lbs.

CHAPTER VIII

ECONOMY IN FEEDING LIVE STOCK

I. Selecting Economical Rations

To secure the largest returns, the stockman must, first of all, understand the fundamental principles governing the feeding of the various classes of live stock, discussed in the preceding chapters. He must next study the possibilities of his farm for crops, paying attention to both their probable yield and their value for feeding to stock or for sale. It is also necessary to consider the feeding value and compare the prices of the many feeds which can be secured on the market. With this knowledge he is in a position to plan his rotations so that from the crops raised, supplemented by purchased feeds when it is economical, well-balanced rations may be provided at the least expense. As a rule it is wise to raise all roughage on the farm. Owing to the demand for the cereal grains for human consumption, it is often economical to sell more or less of the farm-grown grains and replace them with purchased concentrates which may economically supplement the feeds raised on the farm.

Market prices not guides to value.—The market price of a feed is often no index of its value to the individual stockman, as a few examples will illustrate: In the northeastern states timothy hay is generally higher in price than clover hay, tho much inferior for all animals except the horse. In the South cottonseed hulls usually cost more than the sum for which an equivalent amount of corn silage, a much more palatable feed, can be produced on the farm. Owing to their popularity, some feeds, such as linseed meal and wheat bran, are often high in price compared with other concentrates which are entirely satisfactory substitutes. At the other extreme, low grade concentrates, such as trashy corn and oat feed, cottonseed feed, and inferior mixed feeds, often sell for as much or but slightly less than high grade concentrates.

How to select feeds for economical rations.—Many attempts have been made to assign a definite money value to 1 lb. of digestible crude protein, digestible carbohydrates, and digestible fat, and then compute the value of different feeds on the basis of the amount of these nutrients they contain, similar to the manner of arriving at the money value of fertilizers. (See Chapter XVII.) While such a system may be of limited value for a short period of time and when applied to small districts where the systems of farming do not differ widely, no such set of values can be applied generally thruout the United States. This is because the value of any given feed to the stockman depends on the nature and composition of the other feeds he has on hand at the particular time. If his chief roughage is alfalfa hay, protein-rich concentrates are often worth less to him than those rich in carbohydrates. On the other hand, if his roughage is mostly corn or sorghum silage, low in protein, then protein-rich concentrates will be of higher value to him than those of carbonaceous character.

In comparing the relative cheapness of different feeds, it is reasonable to value marketable farm-grown feeds at the market price less the cost of hauling to market. Feeds not marketable may be assigned a value based on the cost of production. To the price of any purchased feeds should be added any cost of hauling to the farm, tho often they may be brought to the farm on a return trip from market with little or no additional expense. In selling crops and buying feed the prudent farmer-stockman will always take into account the value of the fertility gained or lost in the transaction.

In planning economical rations for any class of animals the stockman should first choose a combination, containing the proper proportion of concentrates and roughages, which will supply the necessary total amount of nutrients at the minimum expense. If this ration is too low in protein, the supply should be brought to the desired amount by substituting protein-rich feeds for those lower in protein. On the other hand, if the ration is too rich in protein, then carbonaceous feeds should be substituted until the nutritive ratio is widened sufficiently.

To determine which feeds are the cheapest supplements to balance a ration low in protein, it will be found convenient to compute the cost of the different feeds per pound of digestible crude protein.

A comparison of corn-belt feeds for milk production.—To show how the prices of the available feeds should be studied in computing rations, let us assume that a dairyman in the corn belt has plenty of red clover hay, timothy hay, and corn silage for roughage, and also has considerable corn, oats, and barley. He wishes to feed the grain which is cheapest, considering its actual feeding value, and to sell the rest. Red clover hay is worth $14 per ton on the farm; timothy hay, $15; and corn silage, $4.50. Shelled corn is worth 56 cts. a bushel; oats, 35 cts.; and barley, 55 cts. Adding $2 a ton for grinding, the cost of ground corn will be $22.00 a ton; of oats $23.88; and of barley, $24.92. He can purchase hominy feed at $25.00 per ton, wheat bran at $25.00, gluten feed at $30.00, choice cottonseed meal at $35.00, linseed meal at $35.00, and alfalfa meal at $25.00. For convenience we will arrange in tabular form the data from Appendix Table III for these different feeds, and compute the cost per pound of digestible crude protein and the cost of 1 lb. of total digestible nutrients in each.

Comparison of the economy of various feeds at the prices stated

Feeding stuff	Dry matter in 100 lbs.	Dig. crude protein in 100 lbs.	Total dig. nutrients in 100 lbs.	Nutritive ratio	Price per ton	Cost per lb. of dig. crude protein	Cost per lb. of total dig. nutrients
	Lbs.	Lbs.	Lbs.	1:	Dollars	Cents	Cents
Farm grown grains							
Dent corn, ground	89.5	7.5	85.7	10.4	22.00	14.67	1.28
Oats, ground	90.8	9.7	70.4	6.3	23.88	12.31	1.70
Barley, ground	90.7	9.0	79.4	7.8	24.92	13.84	1.57
Purchased concentrates							
Hominy feed	89.9	7.0	84.6	11.1	25.00	17.86	1.48
Wheat bran	89.9	12.5	60.9	3.9	25.00	10.00	2.05
Gluten feed	91.3	21.6	80.7	2.7	30.00	6.94	1.86
Cottonseed meal, choice	92.5	37.0	78.2	1.1	35.00	4.73	2.24
Linseed meal, old process	90.9	30.2	77.9	1.6	35.00	5.79	2.25
Roughages							
Timothy hay	88.4	3.0	48.5	15.2	15.00	25.00	1.55
Red clover hay	87.1	7.6	50.9	5.7	14.00	9.21	1.38
Corn silage	26.3	1.1	17.7	15.1	4.50	20.45	1.27
Alfalfa meal	91.2	10.2	50.7	4.0	25.00	12.25	2.47

This table does not assume to represent average conditions in any district of the country, but shows how any stockman may compare the relative economy of the different available feeds at local prices. The last column shows clearly that, for the feeds given and with prices as stated, corn is decidedly the cheapest source of total digestible nutrients among the concentrates. Of the roughages, corn silage supplies total digestible nutrients most cheaply, closely followed by clover hay. For balancing a ration low in protein, cottonseed meal will furnish digestible crude protein at 4.73 cts. per pound, linseed meal at 5.79, gluten feed at 6.94 cts., red clover hay at 9.21 cts., and wheat bran at 10.00 cts. In supplying protein these feeds will of course also furnish carbohydrates and fat as well, which are included in the total digestible nutrients.

A corn-belt ration for milk production.—From the feeds listed let us now formulate the most economical ration which will be satisfactory for a 1,200-lb. cow yielding daily 30 lbs. of 3.5 per ct. milk. For this cow there will be required, according to the Morrison feeding standard (Appendix Table V), a minimum daily allowance of 2.31 to 2.67 lbs. digestible crude protein and 18.03 to 18.99 lbs. total digestible nutrients. As is pointed out on Pages 110 and 425, feeding the larger amounts of protein and total digestible nutrients will result in greater production, but sometimes may not be most profitable. The ration should contain from 25 to 30 lbs. of dry matter, and should have a nutritive ratio no wider than 1:6 to 1:7.2.

Altho corn silage is the cheapest roughage available, some dry roughage should be fed with it to dairy cows. Of the dry roughages, clover hay is the cheapest. Let us then follow the general rule of feeding 1 lb. of dry roughage and 3 lbs. of silage per 100 lbs. live weight. To this allowance of roughage, we will add enough corn to bring the total digestible nutrients up to the amount advised in the standard, for corn is the concentrate which furnishes total digestible nutrients most cheaply. Tabulating the results we will have:

First trial ration for corn-belt dairy cow

Feeding stuff	Dry matter	Digestible crude protein	Total digestible nutrients	Cost	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Cents	
Clover hay, 12.0 lbs. . .	10.45	0.912	6.108	8.40	
Corn silage, 36.0 lbs. . .	9.47	0.396	6.372	8.10	
Corn, dent, 8.0 lbs. . . .	7.16	0.600	6.856	8.80	
Total.	27.08	1.908	19.336	25.30	1:9.1

This ration, which costs 25.30 cts., meets the standard in total digestible nutrients and dry matter, but is very deficient in protein. We could narrow the nutritive ratio by feeding less silage and more clover hay, but corn silage is cheaper. Therefore we should substitute protein-rich concentrates for a part of the corn.

If 1.5 lbs. of cottonseed meal was substituted for 1.5 lbs. corn, the ration would furnish 2.3 lbs. of digestible crude protein, the minimum recommended in the standard. Ground corn and cottonseed meal are, however, both heavy feeds, weighing about 1.5 lbs. per quart. (Appendix Table IX.) To furnish more protein and also more bulk in the concentrate mixture and a greater variety of feeds, let us substitute for 3.5 lbs. of corn the following: 1.5 lbs. wheat bran (bulky, palatable, and fairly economical at these prices); 1.0 lb. gluten feed (rich in protein and bulkier than cottonseed meal); and 1.0 lb. cottonseed meal. We will then have the ration given on the next page.

This supplies the minimum amount of protein recommended by the standard, and is slightly above it in total digestible nutrients. Tho costing 2.05 cts. more than the first ration, it is more economical, for it will produce much better results.

Second trial ration for corn-belt dairy cow

Feeding stuff	Dry matter	Digestible crude protein	Total digestible nutrients	Cost	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Cents	
Clover hay, 12.0 lbs. . .	10.45	0.912	6.108	8.40	
Corn silage, 36.0 lbs. . .	9.47	0.396	6.372	8.10	
Corn, dent, 4.5 lbs. . . .	4.03	0.338	3.856	4.95	
Cottonseed meal, 1.0 lb.	0.92	0.370	0.782	1.75	
Gluten feed, 1.0 lb.	0.91	0.216	0.807	1.50	
Wheat bran, 1.5 lbs. . .	1.35	0.188	0.914	1.88	
Total.	27.13	2.420	18.839	26.58	1:6.8

It was explained in Chapter VII that the lower amounts of digestible crude protein advised for the dairy cow in the Morrison standards are the amounts recommended by Haecker, while the higher figures are those advised by Savage. (Appendix Table V.) High-producing cows should be fed as much protein as called for by the higher figures, if this does not greatly increase the cost of the ration. Let us then see how cheaply a ration can be provided containing 2.67 lbs. digestible crude protein, the higher figure advised by the standard. The protein can be added most cheaply by substituting 0.75 lb. more cottonseed meal for corn, as shown in the table:

Third trial ration for corn-belt dairy cow

Feeding stuff	Dry matter	Digestible crude protein	Total digestible nutrients	Cost	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Cents	
Clover hay, 12 lbs.	10.45	0.912	6.108	8.40	
Corn silage, 36 lbs.	9.47	0.396	6.372	8.10	
Corn, 3.75 lbs.	3.36	0.281	3.214	4.12	
Cottonseed meal, 1.75 lbs.	1.62	0.648	1.368	3.06	
Gluten feed, 1.0 lb. . . .	0.91	0.216	0.807	1.50	
Wheat bran, 1.5 lbs. . .	1.35	0.188	0.914	1.88	
Total.	27.16	2.641	18.783	27.06	1:6.1

This ration, which has a nutritive ratio of 1:6.1, costs 0.48 cts. more than the preceding one. Whether it will produce enough more milk to pay for the increased cost will depend on how pronounced is the dairy temperament of the particular cow. Some dairymen might prefer to substitute 1 lb. of linseed meal for 1 lb. of cottonseed meal, thus providing still greater variety. At the prices stated this change would not increase the cost, but would lower the protein a trifle. Reducing the corn 0.75 lb. would bring the total digestible nutrients to 18.140 lbs., about the lower figure recommended in the standard, saving 0.82 cents. When concentrates are high in price, this might be economical, except for high producing cows.

A cotton-belt ration for milk production.—In the preceding example, corn among the concentrates and corn silage among the roughages furnished total digestible nutrients most cheaply. Therefore, the greater the amount of protein-rich feeds used in the ration, the higher was the cost. Often conditions are just opposite to this. For example, often in the South cottonseed meal, which is extremely rich in protein, furnishes total digestible nutrients most cheaply. Accordingly the cheapest ration would be one in which cottonseed meal was the only concentrate fed. However, it is not safe to feed cows such a large amount of cottonseed meal as this would require, as is pointed out on Page 271. Cottonseed meal is not only poisonous when fed in too large amounts, but it is too rich in protein and too heavy to be fed as the sole concentrate to dairy cows. It would therefore be necessary to substitute feeds which were lower in protein and bulkier for some of the cottonseed meal, even tho this would slightly increase the cost.

II. Adapting Systems of Feeding to Local Conditions

Amount of protein to supply.—The illustrations given in the preceding articles show clearly that rations should be adapted to the local conditions. Feeding standards set forth approximately the amount of protein and total nutrients, which, it is believed, should be furnished for the maximum production of flesh, milk, work, etc., and for the highest well-being of the animal. In the Morrison standards a range is indicated in the amount of digestible crude protein advised for most classes of animals. For example, for 2-year-old steers on full feed from 2.0 to 2.3 lbs. of digestible crude protein per 1,000 lbs. live weight are recommended for the first 50-60 days of fattening. When protein-rich feeds cost but little or no more than carbonaceous feeds, it is well to feed as much protein as indicated by the higher figures. On the other hand, when corn or the other grains are relatively cheap it may be better economy to feed no more protein than called for by the lower figures. For example, corn and clover hay alone make a fairly well-balanced ration for fattening cattle and sheep, but the gains are usually slightly increased and a higher finish secured when a small amount of a protein-rich concentrate, like linseed meal is fed. Whether this will be profitable or not depends on the prices of the feeds and on whether the market will pay a better price for the more highly finished animal. Rarely is it advisable to feed much less protein than the lower figures, for the production will be then lowered.

When protein-rich feeds are cheaper than those carbonaceous in character, as in the cotton belt and the alfalfa districts of the West, it will be economy to feed much more than the minimum amounts of protein set forth in the standards. However, protein should not be supplied in such excess as to injure the health of the animals.

Proportion of concentrates and roughages.—To meet the standards for fattening cattle and sheep and for milch cows, fairly liberal amounts of concentrates are required. When concentrates furnish total digestible nutrients nearly as cheaply as do roughages it is advisable to feed as large a proportion of concentrates as is called for by the standards. On the other hand, in many of the alfalfa districts of the West, grain is usually high in price compared with alfalfa hay. Here it may be more profitable to restrict the grain allowance, even tho gains are slower.

FIG. 29.—FATTENING BEEF CATTLE ON GRASS IN THE CORN BELT

On high-priced land, with few acres unsuited for tillage, the stockman has generally found it more profitable to fatten feeder cattle brought from the ranges than to raise his own feeders.

With dairy cows much depends on the productive capacity of the animal. Except when concentrates are unusually high in price, the cow of good dairy temperament will pay for at least a fair amount of concentrates. On the contrary, for a cow of low productive capacity the most economical ration may be silage and legume hay with no concentrates.

Roughing growing animals thru the winter.—The recommendations of the standards for growing cattle and sheep are based upon continuous thrifty growth, and hence call for a limited allowance of concentrates in addition to roughage. The breeder of pure-bred animals who wishes to develop the best there is in his young stock will feed the concentrates needed to keep them growing rapidly. On the other hand, the western beef producer may find it most profitable to carry young stock thru the winter on roughage alone or with but a small allowance of concentrates. Thus fed, they will gain in frame, and, tho losing in flesh, will be thrifty enough in the spring to make good gains on the cheap pasturage.

Finish animals to meet demands of the market.—The wise stockman will keep in close touch with the demands of the market and adjust his feeding operations accordingly. If the market pays a sufficient premium for thoroly fattened animals, he will finish his stock well before marketing them. On the other hand, for local markets which pay no more for a prime carcass than for one carrying less fat, it will not pay to prolong the fattening process or to feed as heavy an allowance of concentrates as is necessary to make the carcass "ripe," or thoroly fat.

FIG. 30.—A BEEF FARM IN NORTHEASTERN KANSAS

On this farm the bottom lands are in corn and the sloping hillsides in hay, while the broken limestone hills in the background are suitable for pasture. Here beef calves are raised and also fattened for market. (From U. S. Department of Agriculture.)

Adapt type of farming to local conditions.—It is outside the field of this volume to discuss in detail the many factors which the stockman should take into consideration in deciding the type of live-stock husbandry in which to engage and the systems and methods to follow. The foregoing paragraphs serve to illustrate how the farm operations and practices should be suited to local conditions, taking into consideration prices of land and labor, nearness to market, and available crops. For example, the beef producer on high-priced land in the eastern part of the corn belt will generally crowd his calves to rapid growth on a heavy allowance of grain and fatten them as baby beef. Or he will raise no cattle, but fatten feeder steers from the western ranges on a liberal allowance chiefly of corn. On the other hand, in the West, where pasture is cheap compared with grain, the stockman will usually follow a less intensive system, roughing his growing stock thru the winter and marketing them from grass as 2- or 3-year-olds, having been fed little grain at any time.

Milk for our cities must come from the surrounding districts which are within shipping distance. Dairymen maintaining herds on high-priced land to meet this demand properly tend to use a minimum acreage as pasture, relying largely on corn silage or soilage during the summer months. They often buy much of their concentrates, for grain can be produced on land farther from market and shipped in at less expense than it may be possible to grow it on their farms. Such a system is not, however, economical for the dairyman remote from the large markets, whose milk is used in the manufacture of butter or cheese. He must adopt a less intensive system of dairying, where the herd is maintained largely on pasture in the summer, since with him land is relatively less expensive than labor.

Fig. 31.—Beef Cattle on the Western Range

In the range districts of the West pasturage is cheap, but concentrates are high in price. Hence beef cattle are raised on the range and sold as feeders to be fattened in the corn belt or other grain raising districts. (From *Breeder's Gazette.*)

The student will realize as he goes on in this book that, while there are no hard and fast rules for successfully managing live stock, a clear understanding of the principles of the nutrition of animals is essential to the highest success. This must be supplemented by good judgment and by a thoro knowledge of the farm animals themselves, which can only be gained by actual experience. He will further find that expensive buildings for housing stock and complex devices for feeding and caring for them are not necessary; that there are no "best" feeds for all conditions; that elaborate and laborious preparation of feed is often wasted; that patent stock foods guaranteed to work miracles enrich, not the farmer, but the manufacturer.

On the other hand, he will come to appreciate that a proper balancing of the rations for his stock not only benefits the animals, but also increases his profits; that comfort for farm stock can be secured in inexpensive, easy ways, and that the operations of preparing and administering feed are really simple when once understood. He will further come to the deep and fundamental realization that animal husbandry under normal conditions is most successful when combined with general farming and the raising of farm crops; that it rests upon pasture lots which are fertilized so as to produce abundant forage and upon tilled fields which are so managed that the fertility is maintained and bumper crops are grown, a large part of which is marketed thru the animals of the farm.

Having discussed in the preceding chapters the fundamental principles governing the rational feeding and care of the various classes of farm animals, let us now consider in detail the value of the many different feeding stuffs for live stock.

QUESTIONS

1. Using local prices for feeds, see if you can find instances where the market price of a feed does not represent its actual feeding value compared with other feeds which are available.

2. Find the local prices for at least six concentrates and four roughages suitable for feeding dairy cows, and compute the cost per pound of digestible crude protein and total digestible nutrients, as on Page 108. Using this data, compute the cheapest ration which will be well balanced and satisfactory in other respects for a 1,000-lb. cow producing 25 lbs. of 4 per ct. milk daily.

3. How would you adapt the amount of protein in the ration to local conditions?

4. When would you feed less concentrates than called for in the feeding standards?

5. Under what conditions would you rough growing beef cattle thru the winter?

6. Discuss other ways in which you would adapt your type of farming to local conditions.

PART II

FEEDING STUFFS

CHAPTER IX

LEADING CEREALS AND THEIR BY-PRODUCTS

I. CORN AND ITS BY-PRODUCTS

The prime importance of Indian corn, or maize, as a grain crop in the United States is shown by the fact that in acreage, in total yield, and in value, it greatly exceeds any other cereal. Corn is grown in every state of the Union, but flourishes best in the great region between the Appalachians and the Rocky Mountain Plateau. A heat loving plant, it thrives best where the nights are warm during the growing season.

Corn as a feed.—Corn is the great energizing, heat-giving, fat-furnishing feed for the animals of the farm. No other cereal yields, on a given space and with a given expenditure of labor, so much food in both grain and forage. On millions of farms successful animal husbandry rests upon this imperial crop.

The corn grain is pre-eminently a carbohydrate bearer, every 100 lbs. containing over 70 lbs. of nitrogen-free extract, which is nearly all starch. In addition, corn is higher than all the other common cereals in fat, or oil, containing 5 per ct. of this energy-rich nutrient. Due to this abundance of starch and oil, it excels as a fattening feed. Being so rich in carbohydrates, corn is naturally low in crude protein. Moreover, the crude protein is somewhat unbalanced, more than half of it consisting of a single kind which lacks

FIG. 32.—THE KING OF CEREALS
On millions of farms the success of animal husbandry depends largely on corn.

some of the amino acids necessary for animal growth. Corn is also unusually low in mineral matter, especially lime (calcium), which is needed in large amounts by growing animals. Indeed, there is but 0.2 lb. of lime in 1,000 lbs. of the grain. In feeding corn we must bear in mind these important facts concerning its composition, and correct its deficiencies by supplementing it with feeds high in protein and calcium. Fortunately, the legume hays, as alfalfa and clover, are rich in the lacking nutrients, and go far toward balancing a heavy allowance of corn. For fattening cattle and sheep corn and legume hay alone make quite a satisfactory, well-balanced ration.

A possible explanation of the great fondness of farm animals for corn lies in its richness in oil. Again, on mastication the kernels break into nutty particles which are more palatable than meal from wheat, for example, which turns to a sticky dough in the mouth.

The corn grain is the chief basis of the production of beef, pork, and mutton thruout the corn belt. For all classes of fattening animals corn may form most of the concentrate allowance, only sufficient of such protein-rich feeds as linseed meal, cottonseed meal, or wheat bran being added to balance the ration. Corn meal is excellent for dairy cows, when mixed with feeds which are bulkier and richer in protein. Trials have shown that when fed to work horses in properly balanced rations corn is a satisfactory substitute for oats. With growing and breeding animals it is especially necessary that corn be supplemented by feeds which contain an abundance of protein and mineral matter. The manner in which corn should be used for feeding the various classes of animals is discussed in detail in Part III.

While corn should be ground for dairy cows, such preparation does not generally pay for horses or pigs. When pigs follow fattening cattle to pick up the grain that escapes mastication and digestion, the steers are most commonly fed ear or snapped corn, or even shock corn. Sheep with good teeth can always grind their own corn.

Races and types of corn.—Three races of corn—dent, flint, and sweet—are of interest to the stockman. In dent corn the starch is partly hornlike and partly floury, rendering the kernel easy of mastication. In flint corn the starch is mostly hornlike and flinty, making the kernel harder for the animal to crush. There is but little difference in the composition of dent and flint corn, and they have the same feeding value. Recent investigations by Steenbock at the Wisconsin Station show that yellow corn is much richer than white corn in fat soluble vitamine. (See Page 58.) This makes yellow corn more valuable than white for animals not otherwise receiving plenty of this vitamine, as pigs not on pasture which are fed corn with such supplements as tankage, linseed meal, or skim milk.

In sweet corn the starch is hornlike and tough. Before hardening, the milky kernels of this race carry much glucose, which is changed to starch as they mature into the shrunken grain. Sweet corn has somewhat more crude protein and fat and less carbohydrates than the other races.

The length of the growing season exerts a deep influence upon the type of corn. In the South the tropical corn stems, 4 or 5 months from planting, carry great ears burdened with grain so high that a man can only touch them by reaching far above his head. At the other extreme, the Mandan Indian in the country of the Red River of the North developed an early maturing race which reached only to the shoulders of the squaw, with tiny ears borne scarcely a foot from the ground on pigmy stalks.

Storage and shrinkage of ear corn.—While old ear corn rarely contains over 12 per ct. of water, freshly husked corn may contain 36 per ct. Ear corn carrying 20 per ct. or more of water will rarely keep if any considerable quantity is stored together. On twisting such ears they will be found to be loose grained and "sappy." Corn is stored mostly on the husked ear in the North, but in the South the husks are left on the ears because of the weevil, a beetle that lives in the kernels unless they are protected. Shelled corn does not keep well in bulk, especially in the summer, and so corn is held in ear form as long as possible.

Seventy lbs. of dry dent ear corn of good varieties yields 1 bushel, or 56 lbs., of shelled corn, but in the early fall buyers frequently demand 75 or 80 lbs., according to the estimated water content. Flint varieties have a larger proportion of cob to grain than does dent corn.

Soft corn.—Corn frosted before the grains mature contains too much water for storage or shipment, and is best utilized by immediate feeding. Soft corn has been fed successfully to swine, and for steers a pound of dry matter in soft corn is equal in feeding value to a pound of dry matter in hard corn.

A late-maturing variety of corn should not be planted in a locality having a short growing season, with the hope of getting a larger yield. The corn will usually not mature, there is great danger of its heating and molding, and the shrinkage is large. As has been shown in Chapter I, the most rapid storage of food in the corn kernels takes place when they are approaching maturity.

Corn meal; corn chop; corn feed-meal.—The term *corn meal*, as applied to feeding stuffs, is most correctly used for the entire ground corn grain, from which the bran, or hulls, have not been removed by bolting. In preparing corn for human food the grain is ground coarsely and the fine siftings and also the bran are removed. The milled product, which is likewise called corn meal, has a more attractive appearance than the entire ground grain, but contains somewhat less protein and fat. Much of the commercial corn meal, particularly in the Mississippi valley, is made from the part of the kernel left after the manufacture of cracked corn or table meal. It is most correctly called *corn feed-meal,* and is equal in feeding value to corn meal from the entire grain. *Corn chop* is a name sometimes applied to ground corn, and also to mixtures of ground corn and corn by-products. On grinding corn the oil it carries soon becomes rancid and gives the meal a stale taste. Hence this grain should never be ground far in advance of use.

Corn cobs; corn-and-cob meal.—When ear corn is ground the product is called corn-and-cob meal. Because of the rubber-like consistency of the cobs, much power is required to reduce ear corn to meal. If the cob particles in corn-and-cob meal are coarse, the animal will not usually eat them, but when finely ground corn-and-cob meal proves satisfactory with most farm animals. Corn cobs contain over 30 per ct. fiber and furnish little more digestible nutrients than oat straw. Any benefit from including the cobs in grinding is therefore not due chiefly to the nutrients the cobs furnish, but to the fact that they make the meal more bulky. This causes it to lie loosely in the stomach, thus aiding the action of the digestive fluids. If the cost of grinding is small, corn-and-cob meal may be preferable to corn meal when fed with heavy concentrates, especially for dairy cows and horses. Including the cobs is not profitable for sheep or pigs.

Composition of the corn kernel.—Before discussing the value of the various corn by-products resulting from the manufacture of human food, it will be helpful to consider the composition of the different parts of the corn kernel. The flinty, or hornlike, starch at the sides and back of the kernel forms nearly half the total weight. About 88 per ct. of this portion is starch, with but 10 per ct. protein, less than 1 per ct. fiber, and but a trace of fat and ash. The floury starch at the tip of the kernel and partially surrounding the germ, which forms about one-fourth of the kernel, is even higher in starch and carries only 7.8 per ct. protein. The hulls and tip caps, which make up 7 per ct. of the kernel, are also composed largely of carbohydrates, tho containing less starch and about 15 per ct. fiber. The hornlike gluten (8 per ct. of the kernel), just under the hull, is rich in crude protein, and the germ (12 per ct. of the kernel) is high in crude protein, ash, and fat.

Starch and glucose by-products.—In the manufacture of commercial starch and glucose from corn, the grain is cleaned and then softened by soaking in warm water, slightly acidified with sulfurous acid. Next it is coarsely ground and the mass passed into tanks containing "starch liquor." Here the germs, which are lighter on account of the large amount of oil they carry, rise to the surface, and are removed. After washing, the residue is then finely ground, and the coarser part, the bran, separated by silk sieves. The remainder, called "starch liquor," which contains the starch, gluten, and fine particles of fiber, is then passed slowly thru shallow, slightly inclined troughs where the starch settles like wet lime, while the lighter ingredients—the gluten, fiber, etc.—are carried off in the current of water. In this process there are thus obtained, (1) the germ, from which

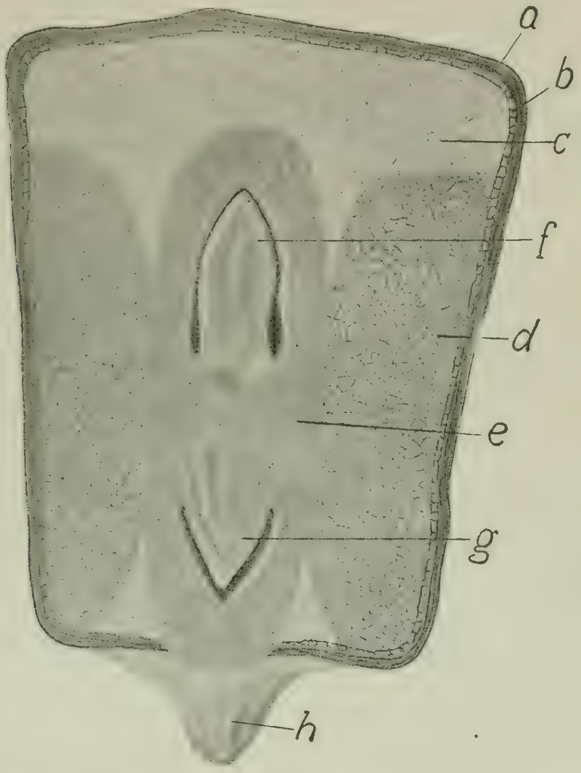

Fig. 33.—Diagram of a Kernel of Dent Corn

A, Hull; b, hornlike gluten; c. floury starch; d, horny starch; e, embryo, or germ; f, embryo stem; g, embryo root; h, tip cap.

corn oil and germ oil meal are secured, (2) the bran, consisting of the hulls, (3) the starch, and (4) the gluten. The bran, together with some light weight and broken germs, was formerly dried and sold as *corn bran*. Now, however, the bran and gluten are usually united while still wet, and then dried and ground, the product being sold as *corn gluten feed,* or *corn starch by-product with corn bran,* as it is sometimes called. The term *corn gluten feed* is used to distinguish this feed from "Continental Gluten Feed," a proprietary name for certain dried distillers' grains.

Corn gluten feed.—Gluten feed contains about 25 per ct. crude protein, 7 per ct. fiber, 53 per ct. nitrogen-free extract, and 4 per ct. fat. It is thus a protein-rich feed. The ash content ranges from less than 1 per ct. to 5 or 6 per ct., depending on whether the steep water in which the corn is softened is evaporated and the residue added to the gluten feed or not. This residue consists of such substances as the soluble protein and phosphates which are dissolved out of the kernels during the soaking process. Gluten feed is extensively used for dairy cows. As it contains about 9 per ct. more digestible crude protein and also furnishes more total digestible nutrients than wheat bran, it is worth considerably more than this feed. It may also be satisfactorily fed to beef cattle, sheep, and swine to supplement carbonaceous concentrates.

Gluten meal.—This by-product, now sometimes called *corn by-product without corn bran,* is one of the richest of concentrates in crude protein and fat, while fair in carbohydrates and low in mineral matter. It is a heavy feed, and, as mentioned before, is usually mixed with corn bran to form gluten feed.

Germ oil meal.—The corn germs removed in the manufacture of starch are dried, crushed, and much of the oil pressed out, leaving the residue in cakes. This is exported as *corn oil cake,* or ground and sold in this country as *germ oil meal* or *corn germ meal.* This feed contains somewhat less protein than the usual gluten feed, but carries a much larger amount of fat.

Hominy feed, meal, or chop.—This by-product, variously called *hominy feed, hominy meal,* or *hominy chop,* is a mixture of the bran, the germ, and a part of the starchy portion of the corn kernel obtained in the manufacture of hominy, of hominy grits, and of table corn meal made by the degerminating process, where the germs are removed from the table meal. It is a carbonaceous feed, similar to corn in composition, but somewhat bulkier. In feeding value it is about equal to corn meal and it has the advantage of being kiln dried, thus keeping better in storage. It is preferred to corn meal for dairy cattle and is also excellent for beef cattle, sheep, and swine.

II. WHEAT AND ITS BY-PRODUCTS IN MILLING

Due to its wide-spread use for human food, wheat is commonly too high in price to be fed in any considerable amount to stock. However, wheat which is frosted, shrunken, or otherwise damaged can be profitably utilized. Tho the market price of such grain is low, it is often equal to wheat of good quality for feeding. Salvage grain, slightly charred or damaged by smoke, may also have its value for stock feeding but little injured.

Wheat as a feed.—Compared with corn, wheat carries slightly more carbohydrates in the form of starch, is higher in crude protein and mineral matter, and contains much less fat. Tho wheat is richer than corn in protein, the protein is unbalanced in composition, as in corn. Like corn, wheat should be supplemented by feeds rich in protein and lime. Fed in properly balanced rations, it is about equal to corn for dairy cows, beef cattle, sheep, and pigs. It should not be fed in large amounts to horses, as it may cause digestive disturbances. Since the kernels are small and hard, wheat should be ground, or better, crushed

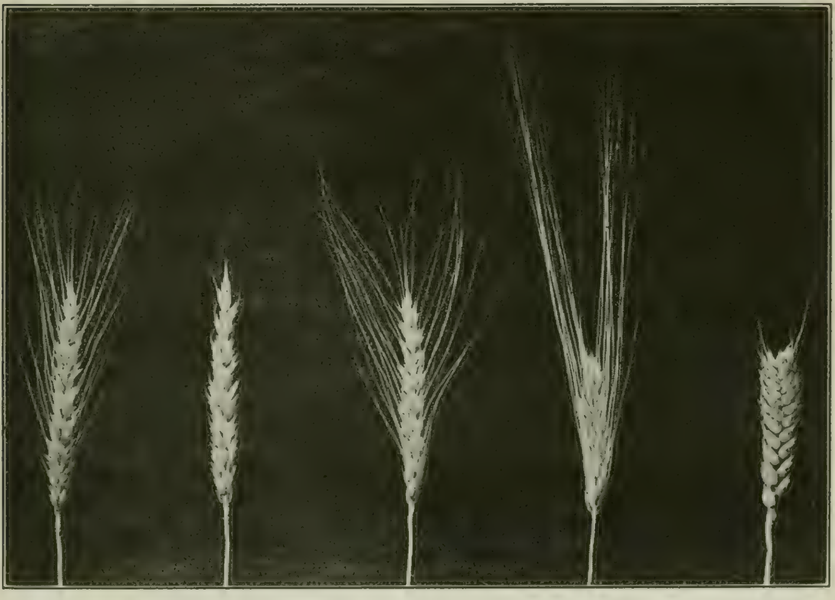

FIG. 34.—HEADS OF DIFFERENT TYPES OF WHEAT

From left to right: 1, bearded winter wheat (Turkey Red); 2, beardless spring wheat (Blue Stem); 3, bearded spring wheat (Velvet Chaff); 4, Durum, or macaroni wheat; 5, club wheat.

or rolled, except for sheep. Finely ground meal or wheat flour forms a pasty mass in the mouth, which can be prevented by mixing with it such materials as bran or coarse corn meal.

There is no appreciable difference in feeding value between spring and winter wheat. Durum or macaroni wheat, extensively grown in the northern plains states, has practically the same composition and feeding value as ordinary wheat.

Flour manufacture.—The wheat kernel is covered with three straw-like coats or skins. Beneath these comes the aleurone layer, high in crude protein. The germ, or embryo plant, in each kernel is rich in oil, crude protein, and mineral matter. The remainder of the kernel consists of thin-walled cells packed with starch grains. Among the starch grains are protein particles called ''gluten,'' that give wheat-flour dough the tenacity needed in bread making. In producing flour the miller aims to secure all the starch and gluten possible from the wheat grains, while avoiding the bran, which makes the flour brownish, and the germs, which soon turn rancid and injure the keeping quality.

In modern milling, flour is produced by passing the thoroly cleaned wheat thru a series of steel rollers, each succeeding pair being set a little nearer together, so that the kernels are gradually crushed into smaller and smaller particles. The flour is removed by sifting or passing the material over bolting cloth, and finally only the by-products remain. These form 25 to 33 per ct. of the weight of the entire grain.

The names of the various mill products differ somewhat in various sections of the country, but those most commonly used are given in the articles which follow.

Wheat bran.—Bran, which consists of the outer coatings of the wheat kernel together with the aleurone layer, is one of the most popular of the cereal by-products for stock feeding. It is fairly rich in digestible protein, and is fair in digestible carbohydrates and fat. It is a most palatable feed, and, being bulky, is excellent to mix with such heavy concentrates as corn, wheat, or barley meal. It also has a beneficial laxative effect, due to a certain phosphorous compound. Bran from mills lacking machinery for perfect separation of the starch from the bran coats is somewhat lower in protein and correspondingly higher in starch than bran from large mills. The difference in feeding value is but slight.

Bran is rich in phosphorus, needed in large amounts by growing animals and those producing milk, but it is deficient in calcium (lime). Due to this lack, horses heavily fed on bran sometimes suffer from ''bran disease,'' which seriously affects their bones. When large amounts of bran are used, it should therefore be fed with feeds rich in lime, such as legume hay, or lime may be supplied as ground limestone or wood ashes.

Owing to its bulky nature and also because it is often high in price compared with other concentrates, bran is not commonly fed to farm animals as the only concentrate, but is mixed with other feeds to add volume or to balance rations low in protein. Its richness in protein and phosphorus, and its beneficial laxative action make it valuable as part of the concentrate allowance for dairy cows, breeding animals of all classes, and young, growing animals. With all horses it is useful, especially on idle days, because of its bulk and laxative effect. It is frequently supplied at least once a week in the form of a bran mash, wet or steamed. It is too bulky and too laxative to form a large part of the ration for hard-worked horses. Bran is often mixed with corn and other heavy concentrates in starting fattening cattle or sheep on feed. It is valuable for brood sows not getting pasture or legume hay, tho too bulky for young pigs or fattening hogs.

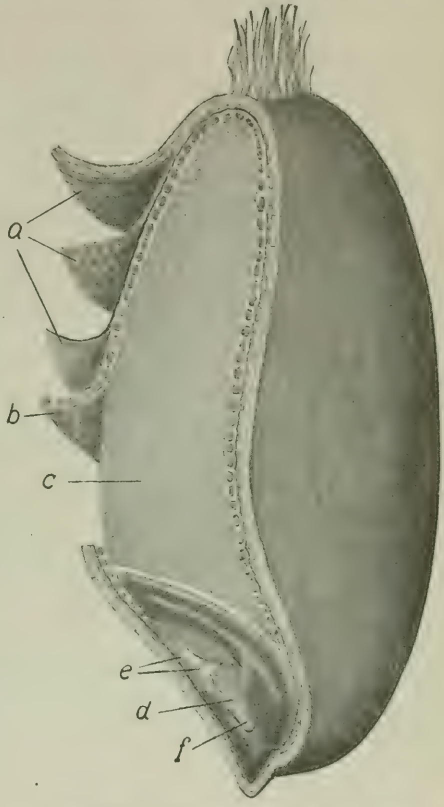

Fig. 35.—Diagram of Wheat Kernel

A, three bran coats; b, aleurone layer; c, cells filled with starch grains; d, embryo, or germ; e, embryo leaves; f, embryo root. (Partially after Neumann.)

Due to its widespread popularity, bran is often high in price compared with other nitrogenous concentrates which can be used with equally good results and many of which carry more protein.

Wheat middlings.—Middlings vary in quality from red dog flour, which contains considerable flour, to standard middlings, or shorts, which may contain but little. To some extent *standard* or *brown middlings* and *shorts* are interchangeable terms. Standard wheat middlings comprise the finer bran particles with considerable flour adhering. Shorts too often consist of ground-over bran and the sweepings and dirt of the mills, along with ground or unground weed seeds. *Flour* or *white middlings* are of somewhat higher grade than standard middlings, for they contain considerable low-grade flour and carry slightly more crude protein and less fiber. Middlings are useful with swine of all ages, but should not be fed as the only supplement to pigs not on pasture. Along with dairy by-products or tankage they give good results. In combination with other feeds they are satisfactory for dairy cows, and they may also be fed to horses in small amounts when mixed with other feeds to avoid colic.

Red dog flour.—Red dog flour, or dark feeding flour, generally contains the wheat germs and is therefore rich in crude protein and fat. Such flour differs little in composition and feeding value from the best flour middlings.

Wheat mixed feed.—Wheat mixed feed, or shipstuff, is, strictly speaking, the entire mill run of the residues of the wheat kernel left after separating the commercial flour. The term is also used for various mixtures of bran and red dog flour or middlings. The value of wheat mixed feed will depend on the proportions of bran, middlings, and flour present, a good grade being superior to wheat bran.

Screenings.—In cleaning and grading wheat at the elevators and mills, there remain great quantities of screenings, consisting of broken and shrunken wheat kernels having high feeding value, mixed with weed seeds and more or less trash. The weed seeds differ widely in feeding value and different lots of screenings vary in the proportions of wheat and trash contained. The best heavy screenings are but little inferior to wheat. Farmers who seek to keep their land free from noxious weeds should see that before feeding the screenings are finely ground to kill all weed seeds. Screenings are now mostly used along with molasses and various other by-products in the manufacture of proprietary feeding stuffs. The feed control laws of several states require that when screenings are present in feeds the fact be indicated on the label and in some cases the percentage must be stated.

III. Oats and Their By-Products

Next to corn, oats are the most extensively grown cereal in the United States. The oat grain is richer than corn in crude protein, and contains nearly as much fat. Due to the woody hull, it contains over 10 per ct. fiber, with correspondingly less nitrogen-free extract than corn or wheat, and accordingly is lower in digestible nutrients and net energy. The hulls of oats form from 20 to 45 per ct. of their total weight, the average being about 30 per ct. As light-weight oats contain more hull and less kernel than plump, heavy oats, their feeding value per pound will be correspondingly less. To increase the weight per bushel and thus make the oats appear to be of a higher grade, the hulls are sometimes "clipped" at the pointed end by machines.

Oats as a feed.—Owing to their bulky character, oats are the safest of all feeds for the horse, in this respect being in contrast to corn. Because of the mettle so characteristic of the oat-fed horse, it was long held that there is a stimulating substance in the oat grain. All claims of the discovery of this compound have, however, melted away on careful examination, and rations containing no oats have given as good results as where oats were fed. For dairy cows there is no better grain than oats, but their use is restricted by their high price. Oats are often mixed with heavy concentrates in starting fattening cattle and sheep on feed. As fattening progresses more concentrated feeds should be substituted for all or most of the oats. Ground oats with the hulls sifted out provide a most nourishing and wholesome feed for young calves and pigs. For breeding swine, whole oats in limited quantity are always in place.

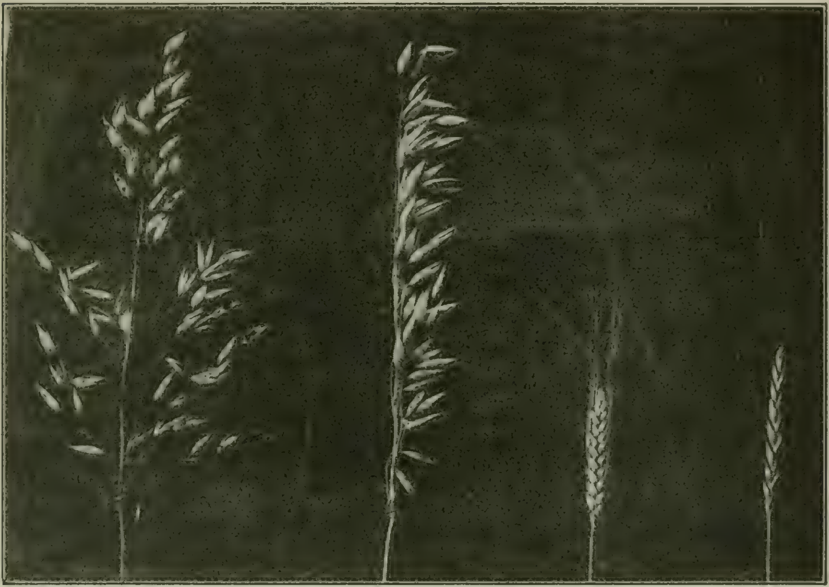

FIG. 36.—HEADS OF OATS, EMMER, AND SPELT

From left to right: 1, Variety of oats with open or spreading panicle; 2, side oats; 3, emmer; 4, spelt.

In recent years the bleaching of low-grade oats and barley with sulfurous acid fumes to whiten the grain has become common. Such grain should be avoided, as it may injure the health of stock.

Oat by-products.—In the manufacture of oatmeal and other breakfast foods, after the light-weight grains are screened out, the *oat hulls* are removed from the remainder, a vast quantity resulting. So completely are the kernels separated that the chaff-like hulls, which contain about 30 per ct. fiber, are worth but little, if any, more than oat straw as a feed. If fragments of the kernels adhere, their value is of course thereby improved. The hulls are used in the manufacture of various proprietary feeds. The addition of a limited amount of hulls to a mixture of heavy concentrates may be beneficial. However, in buying mixed feeds one should not pay as much for a low-grade feed, consisting largely of oat hulls, as for high-grade concentrates.

After the oats are hulled, the fuzzy material covering the kernels is removed, and the kernels are rolled or otherwise prepared for human food. The fuzzy material was formerly known as *oat dust*, but now the term *oat shorts* is applied to this material plus portions of the fine floury part of the kernels removed in the milling process. *Oat middlings* are the floury portions of the kernels obtained in the milling of rolled oats. Commonly these by-products are used in the manufacture of mixed feeds, or they are combined with more or less of the hulls and sold as *oat feed*. The composition and value of oat feeds vary widely, depending on the amount of hulls present. This is shown by the fiber content. These feeds should therefore be purchased only on guarantee of composition and from reputable dealers. *Clipped oat by-product* or *oat clippings*, is the by-product obtained in manufacturing clipped oats. This product, consisting of chaffy material broken from the ends of the hulls, empty hulls, light immature oats, and dust, is used in various proprietary feeds.

Ground corn and oats.—This feed, variously called *ground corn and oats*, *ground feed*, and *provender*, is extensively employed in the eastern and southern states for feeding horses and dairy cows. In composition it ranges from a straight mixture of good-grade corn and oats to one containing a large proportion of low-grade materials, such as oat hulls and ground corn cobs. The best guide to the purity of this feed is the fiber content; when it contains over 7 per ct. fiber, it either has been adulterated or was made from poor-quality oats.

IV. BARLEY AND ITS BY-PRODUCTS IN BREWING

Barley is the most widely cultivated of the cereals, growing in Alaska and flourishing beside orange groves in California. Once the chief bread plant of many ancient nations, it is now used almost wholly for brewing, pearling, and stock feeding. The hull of the grain of ordinary brewing barley or of Scotch barley constitutes about 15 per ct. of its total weight. California feed barley, grown extensively in some sections of the West, has more hull and weighs 45 lbs. or less per bushel; while the usual weight of common barley is 48 lbs. Bald or hulless barley, also grown in the western states, has hard kernels, contains less fiber owing to the absence of the hull, and is as heavy as wheat. Barley has less digestible crude protein than oats, and more than corn. The carbohydrates exceed those of oats and fall below those in corn, while the oil content is lower than in either.

Barley as a feed.—On the Pacific slope, where corn or oats do not flourish in equal degree, barley is extensively used as a feed for animals. For horses crushed barley is worth slightly more than crushed oats. For dairy cows ground barley has proved equal to ground corn. Fed with legume hay to fattening steers and lambs, barley has given very satisfactory results. In Great Britain and northern Europe it takes the place of corn for pig feeding, leading all grains in producing pork of fine quality. Somewhat more barley than corn has been

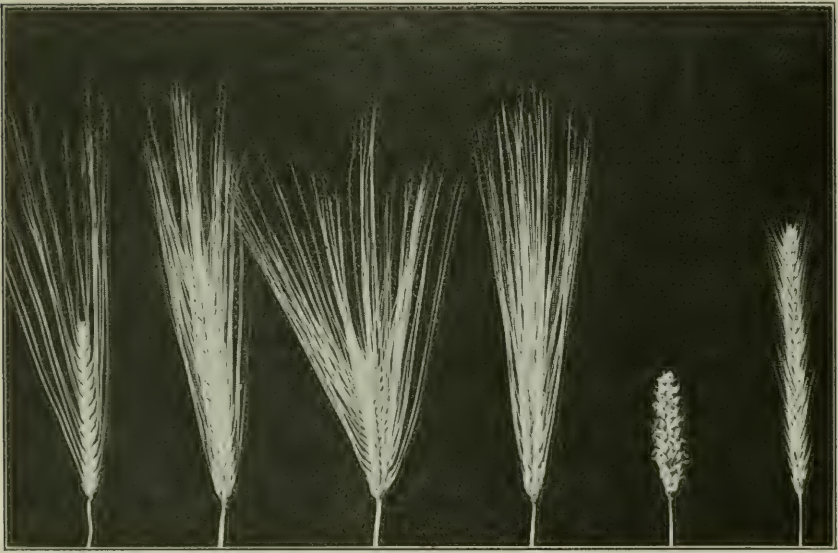

FIG. 37.—HEADS OF DIFFERENT VARIETIES OF BARLEY AND OF RYE

From left to right: 1, Two-rowed barley; 2, common six-rowed barley, or so-called four-rowed barley; 3, true six-rowed barley; 4, California feed barley; 5, beardless barley; 6, rye.

required for 100 lbs. gain with fattening pigs. Owing to its more chaffy nature California feed barley is lower in value than common barley. Tho higher than corn in crude protein, barley is still decidedly carbonaceous in character, and should be fed with legume hay or with a nitrogenous concentrate for the best results.

The malting process.—In making malt the barley grains are steeped in warm water until soft and kept warm until they begin to sprout. The amount of diastase, the enzyme which converts starch into malt sugar, now increases greatly, and when sufficient diastase has been formed in the grain, it is quickly dried. The tiny, dry, shriveled sprouts are then separated from the grains, and put on the market as *malt sprouts.* The dried grains remaining form *malt.* In the manufacture of beer, the malt, after being rolled, is moistened and usually mixed with cracked corn which has been previously cooked. The diastase in the malt now converts the starch in the corn and the malt into malt sugar. This, together with some of the nitrogenous and mineral matter, is then extracted from the mass and fermented by yeast, which forms the alcohol in the beer. The freshly extracted residue constitutes *wet brewers' grains,* which on drying in a vacuum are called *dried brewers' grains* or *brewers' dried grains.*

Dried brewers' grains.—Dried brewers' grains, which keep indefinitely, contain over 70 per ct. more digestible crude protein and twice as much fat as wheat bran, but are lower in carbohydrates, which are largely pentosans. They are nearly as bulky as wheat bran. Dried brewers' grains are widely fed to dairy cows and serve well as part of the concentrate allowance for horses, especially for those at hard work, and needing an ample supply of protein. On account of their bulk, they are not well suited to pigs.

Wet brewers' grains.—Owing to their volume, watery nature, and perishable character, wet brewers' grains are usually fed near the brewery. Containing about 75 per ct. water, they have slightly over one-fourth the feeding value of an equal weight of dried grains. Supplied in reasonable quantity, 20 to 30 lbs. per head daily, and fed while fresh in clean, water-tight boxes and along with nutritious hay and other roughage, there is no better food for dairy cows than wet brewers' grains. However, the wet grains should never be fed to dairy cows unless extreme care is taken to prevent the mangers and surroundings from becoming foul. In Europe the wet grains are considered excellent for fattening cattle and swine when used with dry feed and furnishing not over half the nutrients in the ration. On account of their "washy" nature, they are not commonly used for horses and sheep.

Malt sprouts.—The tiny, shriveled sprouts separated from the dried malt grains form a bulky feed which is rather low in carbohydrates and fat, but carries about 20 per ct. digestible crude protein, one-third of which is amids. At ruling prices they are an economical source of protein, but, not being relished by stock, should be given in limited quantity mixed with other concentrates. Malt sprouts are especially valuable for dairy cows, tho they will not usually eat over 2 or 3 lbs. daily. In Europe horses have been fed as high as 5 to 6 lbs. per head daily with good results, and sheep 0.5 lb. daily per 100 lbs. live weight Since malt sprouts swell greatly when they absorb water, they should be soaked for several hours before feeding.

Barley feed.—This by-product from the manufacture of pearl barley or flour has about the same feeding value as wheat bran, being somewhat lower in protein and higher in nitrogen-free extract.

V. Rye and Its By-Products

Rye, the principal cereal of north Europe, is not extensively grown in America. Tho it repays good treatment, this "grain of poverty" thrives in cool regions on land that will not give profitable returns with other cereals. It furnishes about one-third of the people of Europe with bread, and when low in price or off-grade is commonly fed to stock.

Rye and its by-products.—Tho farm animals show no fondness for rye, they take it willingly when mixed with other feeds. Fed alone or in large amounts it is more apt to cause digestive disturbances than the other cereals. In northern Europe it is a common feed for horses and swine. Fed in large allowance to cows rye produces a hard, dry butter.

The by-products in the manufacture of rye flour are *rye bran* and *rye middlings*, which are usually combined and sold as *rye feed*. All have about the same feeding value as the corresponding wheat feeds, the rye feeds containing less fiber and being somewhat lower in protein and higher in nitrogen-free extract.

VI. Emmer

Emmer, often incorrectly called "spelt" or "speltz," was introduced into America from Germany and Russia. It is a member of the wheat family, altho in appearance the grain resembles barley. Being drought resisting, emmer is valuable in the semi-arid regions of America. In 1909, 12,700,000 bushels were grown, mostly in the northern plains states.

Emmer as a feed.—In composition emmer resembles oats. It may be fed with success to all classes of farm animals, its value being somewhat lower than corn or barley. Like oats, it is rather bulky to use as the sole concentrate for fattening animals, and gives better results when mixed with corn or barley.

QUESTIONS

1. What are the strong and the weak points of corn as a feed?
2. Discuss the differences in composition and feeding value of the three types of corn.
3. How should soft corn be utilized and what is its value?
4. Discuss the composition of the different parts of the corn grain and draw a diagram showing their location in the kernel.
5. Describe the manufacture of starch from corn and name the by-products resulting.
6. What is the feeding value of gluten feed and hominy meal?
7. Compare wheat and corn for stock feeding.
8. Draw a diagram of the wheat kernel and discuss the manufacture of flour.
9. Discuss the value and uses of wheat bran, wheat middlings, red dog flour, wheat mixed feed, and wheat screenings.
10. What are the composition and value for feeding of oats, oat hulls, and oat middlings?
11. Describe the malting process and discuss the feeding value of barley, dried brewer's grains, and malt sprouts.
12. What is the value for stock of rye, rye middlings, and emmer?

CHAPTER X

MINOR CEREALS, OIL-BEARING AND LEGUMINOUS SEEDS AND THEIR BY-PRODUCTS

I. Rice and its By-Products

The production of rice is steadily increasing in Louisiana, Texas, and Arkansas, where over 95 per ct. of the entire crop of the United States is produced. Like wheat, this cereal is used almost entirely for human food, only the by-products from the manufacture of polished or table rice being fed to farm animals.

Rice and its by-products.—In preparing *rough rice* for human food, first the hulls and next the bran, or outer skin of the kernel, are removed. The kernels are then "polished" to remove the creamy outside layer, rich in protein and fat, and to produce an attractive lustre. The resulting floury particles form *rice polish.*

Rough rice and *hulled rice* are commonly fed to stock only when of low grade. The kernels being hard, these feeds should be ground. Rough rice may replace corn in stock feeding, being worth about 7 per ct. more than that grain. Hulled rice is the richest of all cereals in carbohydrates, but relatively low in crude protein and fat. It is worth about 16 per ct. more than corn.

Rice hulls, tasteless and woody, furnish only about one-third as much digestible nutrients as wheat straw. It is also claimed that their sharp, flinty edges and needle-like points are irritating and dangerous to the walls of the stomach and intestines. They should never be fed to stock, but yet are sometimes used to adulterate mixed feeds, or are ground and sold as "husk meal" or "Star bran."

Rice bran, when pure, consists of the outer layer of the rice kernel proper, the germs, and a small amount of hulls not separated in the milling process. When adulterated with hulls, it is called "commercial bran." Unadulterated rice bran is a highly nutritious feed, containing about as much protein as wheat, 11 per ct. fat, and not over 13 per ct. fiber. It may form half the concentrates for horses and mules, is satisfactory for fattening steers, and may be fed to dairy cows and pigs as part of the concentrates. Too large an amount injures the milk of dairy cows and produces soft pork in pigs. The fat in rice bran soon becomes rancid, and the feed may then be distasteful to stock.

Rice polish, equal to corn in feeding value, carries slightly more protein and considerably more fat, but correspondingly less nitrogen-free extract.

FIG. 38.—A FIELD OF RICE IN ARKANSAS

Rice is usually grown on low, level ground under irrigation, tho certain varieties can be grown on upland without irrigation. Note that this field is flooded. (From *The Southwest Trail*, Rock Island Lines.)

II. SORGHUMS AND MILLETS

Numberless millions of people in India, China and Africa rely on the sorghums and millets for their bread. In India more land is devoted to growing these crops than to wheat, rice, and Indian corn combined. In Africa the sorghums are the one ever-present crop, from tropical jungle to desert oasis and mountain valley.

The sorghums.—The sorghums may be divided into two classes—the saccharine sorghums, having stems filled with sweet juices, and the non-saccharine or grain sorghums, with more pithy stems and sour or only slightly sweet juice. The Indian corn plant never gives satisfactory returns if its growth is once checked. The sorghums may cease growing and their leaves shrivel during periods of excessive heat and drought; yet when the soil becomes moist again, they quickly resume growth. This group of plants is thus of vast importance as grain crops for the southern portion of the semi-arid plains region. Between 1899 and 1919 the acreage in the United States of grain sorghums increased from 266,000 to 4,893,000 acres.

Most of the grain sorghum produced in the United States is grown in the Great Plains region, east of the Rocky Mountains, extending from southwestern Nebraska to northwestern Texas, a limited amount also being grown in Arizona, Utah, and California. Thruout much of the grain sorghum belt these crops are more sure, and, even on good soil, give larger yields than corn. The grain sorghums commonly yield 25 bushels per acre, with maximums of 75 bushels for kafir, 46 for milo, and 80 for feterita.[1]

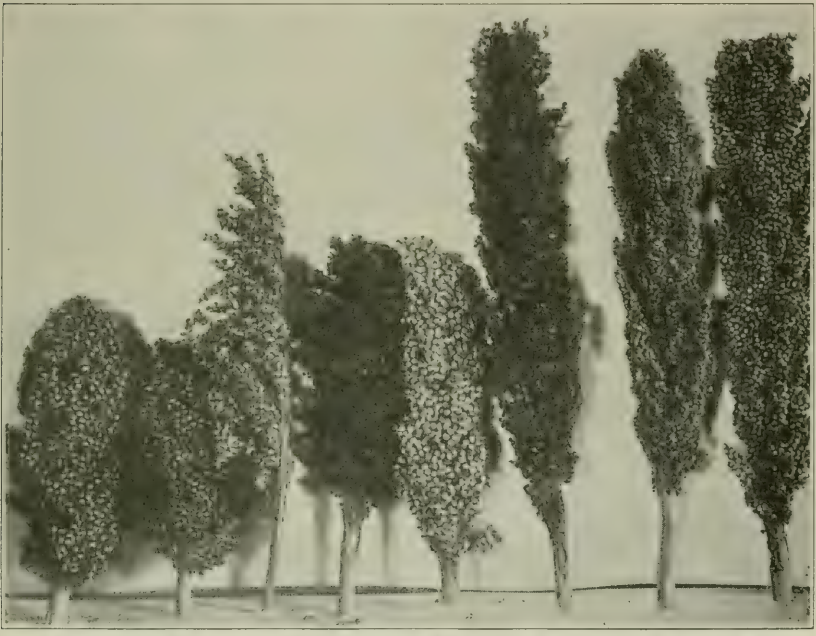

Fig. 39.—Heads of Different Types of Grain Sorghums

From left to right: 1 and 2, yellow milo; 3, white Kaoliang; 4, brown Kaoliang; 5, feterita; 6, red kafir; 7, pink kafir; 8, black-hulled kafir. (From *Breeder's Gazette.*)

Grain sorghums as feeds.—The non-saccharine, or grain, sorghums include *kafir*, *milo*, *feterita*, *kaoliang*, and the less important *durra* and *shallu*. The seeds of the various sorghums are similar in composition, carrying about as much protein and nitrogen-free extract as corn, but 1.5 per ct. less fat. Properly supplemented with protein-rich feeds, they are excellent for all classes of animals. Tho less palatable than corn, their nutritive value ranges from fully equal to this grain to 15 per ct. less. For horses, fattening cattle, dairy cows, and pigs the grain is usually ground, being then called "chop." Grinding for sheep is unnecessary. Often the unthreshed heads are fed, or the forage carrying the heads is supplied, especially to idle horses, colts, and young stock. The product obtained by grinding the entire heads, called "head chop," resembles corn-and-cob meal in composition.

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[1] Piper, Forage Plants, p. 273.

Kafir.—The kafirs lead the sorghums in both grain and forage production in eastern Kansas and Oklahoma. They are stout-stemmed, broad-leaved plants, having slightly sweet juice and long, erect, cylindrical heads carrying small egg-shaped seeds. The kafirs do not sucker, nor do they lodge or shatter the grain. In good seasons and on fertile soil yields of 50 bushels or over are secured. As kafir grain is astringent and constipating, it is best fed with alfalfa or clover hay, or other laxative feeds.

Milo.—Next to kafir, milo is the most important of the grain sorghums. It is less leafy than kafir, and hence is not as valuable for forage. The heads are short and thick, goose-necked in most varieties, and with large flat seeds. As it is earlier, milo outyields kafir in the extreme west of the sorghum belt. Unlike kafir, milo has a slight laxative effect.

Feterita.—This type has erect heads and slender stems with more leaves than milo but less than kafir. It yields as much grain as kafir, tho less forage, and is of importance for the western part of the grain sorghum belt. Unfortunately, it stools and lodges badly.

Kaoliang.—These early-maturing sorghums from northern China are especially suited to the northern plains district, where the other types will not mature. The kaoliangs yield as much grain as the milos and will stand drought better, but the forage is scanty and of poor quality, the stalks being pithy and the leaves few.

Sweet sorghums.—The sweet sorghums, or *sorghos*, are forage rather than grain producers, and are therefore discussed more fully in Chapter XII. For grain production they are surpassed by corn in the humid regions and by the grain sorghums in the plains districts. The seed is not as palatable nor of as high feeding value as kafir or milo.

Millets.—The millets chiefly grown in this country are: (1), the foxtail millets, all resembling common foxtail or pigeon grass in appearance; and (2), the broom corn, proso, or hog millets, which have spreading or panicled heads, wide hairy leaves, and large seeds. The forage types are considered in Chapter XIII. In humid regions millets are chiefly sown in early summer as catch crops, owing to the short period required for growth. In the northern plains district, where the growing season is too short for the sorghums, they are of increasing importance for grain production. The yields reported range from 16 to over 30 bushels per acre. Ground millet seed has been successfully used for fattening cattle, lambs, and pigs, tho usually of somewhat lower value than corn.

III. Buckwheat and its By-Products

Altho rarely used for feeding stock, buckwheat has a fair value for such purpose, its nutrients running somewhat lower than those in the leading cereals.

Buckwheat by-products.—The black, woody hulls of the buckwheat grain have little feeding value. On the other hand, *buckwheat middlings,* that part of the kernel immediately under the hull, which is separated from the flour on milling, contains 28 per ct. crude protein and 7 per ct. fat, with little fiber, and is equal to dried brewers' grains in value. To dispose of the hulls, millers usually mix them with the middlings, selling the combination as *buckwheat bran* or *feed.* The value of such feed depends entirely on how much hulls are present. This can be told from the amount of fiber it contains. Buckwheat by-products are nearly always used for dairy cows, but should not be fed as the only concentrate or the quality of the milk may be injured.

IV. Oil-Bearing Seeds and their By-Products

The annual crop of cotton in the United States now amounts to over 11,000,000 bales of 500 lbs. each, with about 5,000,000 tons of cotton seed as a by-product, since for each pound of fiber, or lint, there are nearly 2 lbs. of seed. Before 1860 the seed of the cotton plant was largely wasted by the planters, who, ignorant of its worth, often allowed it to rot near the gin house, while meat and other animal products which might have been produced from it were purchased at high cost from northern farmers. The utilization of the cotton seed and its products as food for man and beast furnishes a striking example of what science is accomplishing for agriculture.

Cotton seed.—The cotton seed carries about 19 per ct. fat, or oil, and nearly 20 per ct. crude protein. Formerly much seed was fed in the South, especially to steers and dairy cattle. Now little is fed before the oil is extracted, both on account of the value of the oil and because cottonseed meal usually gives better results. Owing to the high oil content, cotton seed sometimes has an unduly laxative effect. Wet, moldy cotton seed or that which has heated should never be fed.

Cottonseed cake and meal.—At the oil mills the leathery hulls of the cotton seed, which are covered with short lint, are cut by machinery, and the oily kernels set free. These kernels are crushed, heated, placed between cloths, and subjected to hydraulic pressure to remove the oil. The residue is a hard, yellowish, board-like cake about one-half inch thick, 14 in. wide, and 34 in. long. For the eastern and central states the cake is generally ground to a fine meal, for the western trade it is often broken into pieces of pea or nut size for cattle and coarsely ground for sheep, while the export cake is commonly left whole. For feeding out of doors the broken cake is preferable to meal as it is not scattered by the wind. Unadulterated cottonseed meal of good quality should have a light yellow color and a sharp, nutty odor. A dark or dull color may be due to age, to adulteration with hulls, to overheating during the cooking process, or to fermentation—all of which injure its feeding value.

FIG. 40.—PICKERS IN A FIELD OF COTTON

Over 2,500,000 tons of cottonseed meal are produced annually in this country as a by-product of the cotton crop. Used rightly, this rich concentrate is one of the most valuable feeds for stock. (From Louisville and Nashville Railroad.)

Cottonseed meal is one of the richest of all feeds in protein and carries over 8 per ct. of fat. Since the protein and fiber content vary considerably, depending chiefly on how thoroly the hulls are removed from the meal, manufacturers and feed control officials have agreed on the following classification:

Choice cottonseed meal must be perfectly sound and sweet in odor, yellow, not brown or reddish, free from excess of lint, and must contain at least 41 per ct. of crude protein.

Prime cottonseed meal must be of sweet odor, reasonably bright in color, and must contain at least 38.6 per ct. of crude protein.

Good cottonseed meal must be of sweet odor, reasonably bright in color, and must contain at least 36 per ct. of crude protein.

Cottonseed feed is a mixture of cottonseed meal and cottonseed hulls, containing less than 36 per ct. crude protein.

Owing to its wide variation in composition, cottonseed meal should be purchased on guarantee whenever possible.

Cottonseed feed.—On northern markets cottonseed feed, consisting largely of hulls, is often sold for only a little less than choice cottonseed meal. Yet average cottonseed feed contains but 24.5 per ct. crude protein, and is thus worth only 60 per ct. as much as choice cottonseed meal. Since it is impossible to tell finely ground cottonseed feed from the best cottonseed meal by its appearance alone, the wise feeder will always buy cottonseed meal from reliable dealers.

Cold-pressed cottonseed cake.—Cold-pressed cottonseed cake, or "caddo" cake, is produced by subjecting the entire uncrushed, unheated seed to great pressure. In this cake there is a larger proportion of hull to meal than in the usual cottonseed meal, with correspondingly lower feeding value. This product is usually sold in nut or pea size but is sometimes ground to a meal. The crude-protein content of cold-pressed cake is a reliable guide to its feeding value.

The poison of cotton seed.—Experience and scientific trials unite in showing that cotton seed or cottonseed cake or meal is not always a safe feed. After about 100 days steers closely confined and heavily fed on meal often show a staggering gait, some become blind, and death frequently ends their distress. Cottonseed meal is most poisonous to swine. Pigs getting as much as one-third of their concentrates in the form of cottonseed meal thrive at first, but after a few weeks they become sick and may die.

During the past 20 years numerous attempts have been made to find the cause of the poisonous effect, and many different reasons have been advanced by scientists. Further work has, however, failed to prove that the fatal effect is due to any of the causes assigned. Recently, Withers of the North Carolina Station[2] has attributed the poisonous quality to a substance called "gossypol," which is formed in certain cells of the seed. It is to be hoped that further work may reveal

[2] Jour. Agr. Res., 5, 1915, pp. 261–88.

methods by which this rich feed can be used with safety for all classes of animals.

Feeding cottonseed meal and cake.—Cottonseed meal is one of the most valuable of feeds when properly fed, often being the cheapest available source of protein, and thru it, of nitrogen for maintaining soil fertility. It does not have the beneficial laxative effect of linseed meal, but instead is somewhat constipating. More care is necessary in feeding it, tho when given in proper combination with other feeds equally good results may be secured with dairy cows, horses, fattening cattle and sheep as with linseed meal. The amounts which may be safely fed to each kind of stock are fully discussed in the respective chapters of Part III. The most extensive use of cottonseed meal is by dairymen, for comparatively heavy allowances may be fed to milch cows without harm. Fed in too large amounts, cottonseed meal produces hard, tallowy butter, light in color and poor in flavor. A limited quantity has little effect, and is even helpful with cows whose milk produces a soft butter.

For fattening steers and sheep cottonseed meal, in limited amount, is one of the most satisfactory of nitrogenous supplements. Great numbers of steers are fattened at the oil-mill factories, often on a ration of 6 to 8 lbs. of cottonseed meal with cottonseed hulls or corn silage for roughage. In restricted amounts, mixed preferably with bulky feed, cottonseed meal has been fed to horses and mules with entire success. Altho cottonseed meal is especially poisonous to swine, some feeders, guided by experience, use it in small amounts and for short periods with little loss. Calves are easily affected by its poisonous properties. Cottonseed meal having a dull color due to improper storage, and that from musty and fermented seed should never be used for feeding stock.

This most nutritious feed, the richest in fertilizing constituents of all our common feeds of plant origin, is often spread directly on the land as a fertilizer in some parts of the country. To secure the full value, the meal should first be fed to animals and the resulting manure applied to the soil.

Cottonseed hulls.—Cottonseed hulls, which contain somewhat less digestible nutrients than oat straw, are extensively employed in the South as roughage for cattle feeding. Low in crude protein, but a small part of which is digestible, they have a nutritive ratio of 1:122, the widest of any common feeding stuff. Obviously, they should be used with feeds which are rich in protein. Cottonseed hulls are best suited to beef cattle, large numbers of steers being fattened on cottonseed hulls and cottonseed meal, with or without silage. They are not well adapted to dairy cows, corn stover having a higher feeding value.

Flax seed and linseed oil manufacture.—Over 95 per ct. of the flax seed crop of the United States is produced in Minnesota, the Dakotas, and Montana. Because of the valuable oil it yields, flax seed is rarely used for feeding stock other than young calves. Well-matured flax seeds contain no starch, the reserve plant food being stored largely as oil and pentosans, instead.

The oil of the flax seed is either extracted by the "old process," thru crushing and pressure, as in the production of cottonseed oil, or by the "new process," when it is dissolved out of the crushed seed with naphtha, the residue in either case being called *linseed oil meal, linseed meal,* or simply *oil meal.* In the United States nearly all the linseed oil meal is made by the old process.

In the manufacture of new-process oil meal the crushed and heated seed is placed in large cylinders or percolators, and naphtha poured over the mass. This drains out at the bottom carrying the dissolved oil. After repeated extractions all traces of the naphtha are driven off by letting steam into the percolator.

Old- and new-process oil meal.—Since the oil is extracted much more thoroly by the naphtha process, new-process meal contains only about 2.9 per ct. of oil or fat, but carries slightly more digestible protein. Old-process meal is preferred by feeders, since it apparently has a more laxative action and a more pronounced effect in making the coats of animals soft and sleek, due probably to its higher oil content.

Linseed meal as a feed.—There is no more healthful feed for limited use with all farm animals than linseed cake or meal, with its rich store of crude protein, slightly laxative oil, and its mucilaginous, soothing properties. Its judicious use is soon apparent in the pliable skin, the sleek, oily coat, and the good handling quality of the flesh of animals receiving it. It is therefore very useful as a conditioner for run-down animals and in fitting animals for shows. A small amount is helpful in the rations of horses and dairy cows. Opposite in effect to cottonseed meal, linseed meal tends to produce soft butter. Fed to fattening cattle, sheep, or swine, the meal regulates the system and helps to ward off ill effects from the continued heavy use of concentrates. Rich in protein and all the necessary mineral elements, linseed meal is well suited to growing animals. Owing to its popularity, this feed is often expensive compared with other protein-rich concentrates, and it is then not economical to employ it as the chief source of protein in the ration, but to restrict its use to amounts sufficient to produce the desired tonic and regulative effects.

In this country the demand is chiefly for linseed meal instead of the unground cake, probably due to the fact that it is mostly fed mixed with other concentrates to dairy cows. For sheep, cake ground to nut or pea size is preferable.

Low-grade linseed meal; other flax products.—Pure old-process linseed meal usually contains over 32 per ct. protein, but some concerns are putting on the market lower grade mixtures of linseed meal and screenings, carrying as low as 27 per ct. protein. These are rarely economical at the prices asked, as they often sell for nearly as much as a good grade of linseed meal.

Flax feed, which consist of flax screenings, is chiefly used in mixed feeds. Containing only half as much protein as linseed meal and often having a bitter taste due to weed seeds, it is rarely economical.

Flax plant by-product, sometimes sold incorrectly as "flax bran," consists of flax pods, broken and immature flax seeds, and portions of the stems. Owing to its low value, it is rarely sold alone, but is used as a "filler" in certain proprietary feeds.

Unscreened flax oil-feed, or "laxo" cake meal, is the by-product obtained in extracting the oil from unscreened flax seed. The value is lower than that of linseed meal, depending on how much screenings it contains.

Soybean.—The soybean is one of the most important agricultural plants of northern China and Japan. The bean-like seeds, which carry from 16 to 21 per ct. of oil, are used for human food and for feeding animals. The oil is also used for human food and in the arts, and the resulting *soybean meal* is employed as a feed for animals and for fertilizing the land, the same as cottonseed meal. This plant produces the largest yield of seed of any legume suited to temperate climates, tho now grown in this country chiefly for forage. No other plant so little grown in the United States at this time promises so much to agriculture as the soybean, which not only yields protein-rich grain and forage but builds up the nitrogen content of the soil. Soybeans are adapted to the same range of climate as corn, and, on account of their resistance to drought, are especially suited to light, sandy soils. When grown for seed, they commonly yield 12 to 40 bushels per acre.

The seeds contain as much protein and over twice as much fat as linseed meal, and are of nearly as high feeding value as cottonseed meal. Owing to their richness in protein, soybeans should always be fed with carbonaceous concentrates. They are satisfactory for dairy cows and growing and fattening stock of all classes. In the South pigs are often grazed on the nearly mature beans, saving the labor of harvesting. Fed in large amounts, they make soft butter and pork. Soybeans should be ground for horses and cattle. Owing to the high price the seed commands, soybeans have not yet been extensively fed to live stock in this country, most of the crop being used for seed or for forage. (See Chapter XIV.)

Soybean cake or meal.—The residue after the oil has been extracted from soybeans carries as much digestible protein as choice cottonseed meal, and furnishes slightly more total digestible nutrients. During recent years a considerable amount has been imported from the Orient to the Pacific coast states, where it is highly esteemed for feeding poultry and dairy cattle. In Europe the unground cake is used and in this country the meal. Tho high in price, soybean meal is greatly esteemed by western dairymen, and is often fed in large amounts to cows on official tests.

The peanut and its by-products.—The peanut, or earth nut, is now of great importance for stock feeding in the South. The underground seeds, or nuts, are commonly harvested by turning swine into the fields when the seeds are ripe, and allowing them to feed at will. While a heavy allowance of peanuts makes soft fat and inferior pork, entirely satisfactory ham and bacon are produced when pigs are fed partially on peanuts. On exposure to the air, shelled peanuts soon become rancid. The vines with the nuts attached may be gathered and cured into a nutritious, palatable hay useful with all kinds of stock.

Peanut meal or *cake*, resulting from the manufacture of peanut oil, is a common feed in Europe, being satisfactory for all classes of stock. Meal from hulled nuts is richer in protein than choice cottonseed meal. Considerable peanut meal is now produced in this country. This is chiefly from unhulled or only partially hulled nuts. The value depends on the protein content. Peanut meal is excellent for dairy cows, beef cattle, sheep, and pigs. Too much may cause soft pork.

Peanut hulls, sometimes ground and used for adulterating feeding stuffs, are over half fiber and less valuable than common straw.

Sunflower seed and oil cake.—The sunflower is grown in considerable quantities in Russia but has never assumed any importance in this country, chiefly because corn yields much more feed per acre. Oil cake from sunflower seed has proved satisfactory for all classes of stock in Europe, being nearly equal to linseed meal.

Cocoanut meal.—This residue in the manufacture of oil from the cocoanut is lower in crude protein than the oil meals previously discussed, but higher than wheat bran. It is used to some extent by dairymen in the Pacific coast states and produces butter of good quality and firmness. It may also be fed with success to horses, sheep, and swine. Cocoanut meal, especially that high in fat, has a tendency to turn rancid in warm weather.

V. OIL-FREE LEGUMINOUS SEEDS

The Canada field pea.—The common field or Canada pea succeeds best where the spring and summer heat is moderate, as in Canada, the northern states, and in several of the larger Rocky Mountain valleys. No other widely known grain plant of equal possibilities has been so generally neglected by the farmers of the northern United States. Field-pea grain contains twice as much crude protein as the cereals and is high in phosphorus. Fed with corn, peas may form as much as one-half the concentrates for dairy cows. They are relished by horses and are excellent for sheep and pigs, being of especial value for growing and breeding animals.

FIG. 41.—COWPEAS ARE OF GREAT IMPORTANCE TO THE SOUTHERN STOCKMAN

The cowpea, the most important legume in the cotton belt, grows on all types of soil, increasing the fertility of the land and furnishing rich feed. (From the *Southern Cultivator.*)

Cowpea.—This bean-like plant from India and China holds an important place in southern agriculture because of its large yield of forage, and early varieties are now grown as far north as Illinois. Since the seed pods ripen unevenly, they must be gathered by hand, or else the crop is cut when about three-fourths of the pods are ripe, and before the first pods are shattered or damaged. For this reason cowpeas are used mostly for hay, silage, and grazing. (See Chapter XIV.) The seed, which resembles field peas in composition, may be fed to all classes of animals.

The common field bean.—Many varieties of the common field bean are grown in this country for human food, and the cull beans damaged by wet are used for animal feeding. They are fed whole in large quantities to sheep, producing a solid flesh of good quality. For swine, beans should be cooked in salted water and fed in combination with corn, barley, etc.; fed alone they produce soft pork and lard with a low melting point.

QUESTIONS

1. Discuss the value of rice and its by-products for stock feeding.
2. Why are the sorghums important in the semi-arid districts? Into what two classes are they divided?
3. Name four types of grain sorghums and discuss their value.
4. Describe the process of making cottonseed oil and cottonseed meal. Into what classes is cottonseed meal divided?
5. How would you use cottonseed meal in stock feeding?
6. What is the difference between old- and new-process linseed meal?
7. Compare linseed meal and cottonseed meal as feeds.
8. Discuss the value of soybeans and soybean meal.
9. What is the chief use of peanuts for stock feeding?
10. Name three oil-free leguminous seeds and state their use for farm animals.

CHAPTER XI

MISCELLANEOUS CONCENTRATES—FEEDING STUFFS CONTROL—CONDIMENTAL FOODS

I. Cow's Milk and its By-Products

Milk is unexcelled as a food for young animals, because it contains all the nutrients in proper proportion to produce rapid growth. The proteins are usually well-balanced and are thus more efficient for growth than those of the cereals. Milk is also rich in mineral matter, especially lime and phosphoric acid, and in the fat-soluble vitamine. For the best profits from dairying, the dairy by-products must be fed in such a manner as to secure their full value.

Whole milk.—Because of the high value of whole cow's milk for human food it is not commonly fed to stock, except to calves for the first few weeks. However, one should not hesitate to use whole milk for rearing an orphan foal or lamb or in fitting young stock for show.

Whole milk contains from 2.5 to 4.0 per ct. protein, which consists chiefly of casein, with 0.4 to 0.9 per ct. albumin and traces of other proteins. It carries from 4 to 5 per ct. of milk sugar, a carbohydrate, which is only slightly sweet and has about the same feeding value as starch. When milk sours, some of the sugar is changed to lactic acid, which curdles the casein. As is shown in Chapter XX, the fat content of cow's milk varies widely, depending chiefly on breed, individuality, and the portion of the milk drawn, the strippings being much the richest in fat.

Experiments by Beach at the Connecticut (Storrs) Station[1] show that for calves, lambs, and pigs milk rich in fat is less valuable per pound of total dry matter than milk poor in fat, or even skim milk. Rich milk may cause digestive troubles, especially with very young animals.

Skim milk.—Being rich in protein and mineral matter, skim milk excels in building the muscles and bones of young animals. Separator skim milk contains 3.8 per ct. protein, 5.2 per ct. nitrogen-free extract, and 0.1 to 0.2 per ct. fat. It is thus a protein-rich feed, having the narrow nutritive ratio of 1:1.5. Therefore, even for young animals it should be fed with such carbonaceous feeds as corn, rather than with protein-rich feeds like wheat middlings and linseed meal. Careful dairymen raise just as thrifty calves when skim milk is gradually substituted for whole milk during the first 4 to 6 weeks, and only skim milk given thereafter, as when expensive whole milk is fed longer. For swine, especially young pigs, skim milk is unsurpassed as a supplement to the carbonaceous grains. The money value of skim milk as a supplement to the grains for pigs is discussed in Chapter XXVIII. Foals whose dams furnish insufficient milk thrive on skim milk. It may also be fed to horses and poultry. Skim milk is most valuable for young animals when it comes sweet and warm from the separator.

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[1] Conn. (Storrs) Bul. 31.

Buttermilk.—This by-product, much like skim milk in composition, is about equal to skim milk for pigs. Sometimes calves are reared on it, but extreme care is necessary in accustoming them to it and in keeping all utensils clean. Buttermilk diluted at the creamery with water has its value reduced. If kept in filthy tanks it ferments and becomes dangerous.

FIG. 42.—Skim Milk Is Ideal for Young Animals, as It Is Rich in Protein of the Highest Quality and in Mineral Matter. (From Wisconsin Station.)

Whey.—Whey contains the sugar, albumin, and a large part of the ash of milk, while the casein and most of the fat go into the cheese. Whey contains only 0.8 per ct. protein, but this is of excellent quality to balance the deficiencies of the protein in the grains. (See Page 366.) More watery than skim milk, it contains only 6.6 per ct. dry matter. Whey is usually fed to pigs, for which it has about half the value of skim milk. At best, it is a poor feed for calves, and can be successfully used only by exercising the utmost care and cleanliness. Slightly soured whey gives as good results as when sweet, but decomposing whey kept in filthy vessels is unfit for stock.

Spreading disease thru dairy by-products.—Since milk from many farms is mixed at the creamery and cheese factory, unless the skim milk, buttermilk, and whey are thoroly pasteurized at a temperature of 180° F. before being taken back to the farms, bovine tuberculosis and other diseases may be widely spread from possibly a single diseased herd. The pasteurized product also keeps better and is less likely to produce scours.

A trial at the Iowa Station [2] shows how readily tuberculosis may be spread thru skim milk. Forty pigs, supposedly free from tuberculosis, were divided into 4 lots. Two lots were kept on separate pastures and two in dry lots. Corn and pasteurized skim milk were fed to all. However, the germs of tuberculosis were put into the milk of one lot on pasture and one lot in the yard, just before feeding. After 196 days the pigs were slaughtered. It was found that every animal in the 2 lots receiving infected milk, 20 in all, was tuberculous, while of those not given infected milk, 2 were tuberculous and 18 free from the disease.

II. Packing House By-Products

The packing house by-products, tankage or meat meal, meat scrap, dried blood, and meat-and-bone meal, are extremely rich in highly digestible, well-balanced protein. Most of them are also rich in calcium and phosphorus, since they contain more or less bone. As they are high in price, the feeder should understand their nature and economical use.

Tankage or meat meal.—At the packing plants waste meat, scrap bones, and fat trimmings are thoroly steam-cooked under high pressure. The fat, while yet liquid, is drawn off and the residue is then dried and ground to a fine meal. The resulting tankage, also called meat meal, contains from 40 to 60 per ct. protein and from 1 to 10 per ct. fat. The variation in protein is due chiefly to the amount of bone present. On account of the wide range between different grades, tankage should always be purchased on guarantee of composition, for the value depends primarily on the protein content. Being thoroly cooked under pressure, tankage is sterilized, so that it cannot carry disease to animals fed on it. In the manufacture of the best grades of tankage, carcasses condemned because of disease are not used.

Tankage or meat meal is generally fed to pigs and poultry, ranking next to skim milk as a supplement for corn and other carbonaceous grains. Owing to its richness in protein, 10 per ct. of tankage fed with 90 per ct. of corn or other cereals is sufficient to balance the ration for pigs over 100 lbs. in weight, but younger ones need somewhat more. Mixed with other feeds, it may be fed to cattle, sheep, and horses, especially colts. If much bone is present, the product is termed meat-and-bone meal. This is used chiefly for poultry. The lower grades of tankage are sometimes adulterated with hair or peat.

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[2] Iowa Bul. 92.

Meat scrap.—Meat scrap, used for poultry feeding, consists chiefly of meat trimmings which have been cooked to extract as much of the fat as possible and then ground to varying degrees of fineness. It resembles tankage in composition, the content of protein and mineral matter varying quite widely, due chiefly to the amount of bone present.

Pork cracklings.—This residue from the manufacture of lard is not commonly found on the market but may often be obtained cheaply from local slaughter houses. Pork cracklings contain over 30 per ct. fat and about 7 per ct. less protein than the best grades of tankage. They are fully as valuable as tankage for swine.

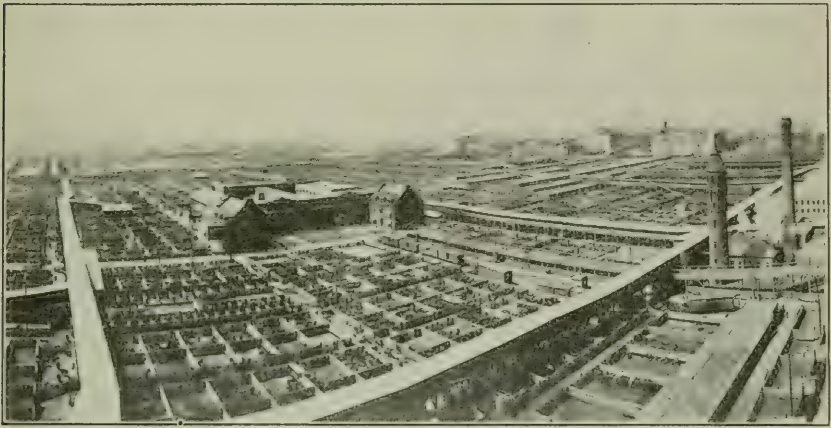

FIG. 43.—A PORTION OF THE UNION STOCK YARDS AT CHICAGO

The Chicago Union Stock Yards occupy an area of 500 acres, and have 25 miles of streets and 300 miles of railway tracks. The yards would hold at one time 75,000 cattle, 125,000 sheep, 300,000 hogs, and 6,000 horses and mules. Some of the large packing plants may be seen in the background at the right.

Blood meal.—Blood meal or dried blood (sometimes called blood flour when finely ground) carries over 80 per ct. protein, but no bone, and is therefore low in ash. It is usually high in price and is not fed extensively except to young pigs or calves as a milk substitute, and to sickly animals. One to 2 lbs. per head daily has been found satisfactory for dairy cows.

Dried fish; fish meal.—In Europe dried fish and fish meal, which are nearly as high in protein as tankage, are often used for feeding stock. In this country fish meal has proven to be an excellent protein-rich feed for swine, being about equal to tankage

Bone meal.—When rations lack calcium and phosphorus, these vital mineral nutrients may be furnished in the form of bone meal, also called ground bone. Ground rock phosphate is usually a cheaper and probably as effective a mineral supplement. Bone meal is used chiefly for pigs and poultry.

III. SUGAR FACTORY BY-PRODUCTS. OTHER FEEDS

In making beet sugar the beets are first washed and then cut into v-shaped strips. Next the juice is extracted, leaving the by-product known as *wet beet pulp.* The juice is then purified and evaporated until the sugar crystallizes. Finally, the grains of sugar are separated from the residual *molasses* by centrifugal force.

Wet beet pulp.—This watery feed which contains only about 10 per ct. of solids spoils rapidly on exposure to the air, and is therefore usually fed as soured or ensiled pulp. It may be ensiled in an ordinary silo, in earthen pits, or in large heaps above the ground where the decay of the outside layer protects the interior from the air. Tho carrying only 1 to 2 per ct. of sugar, wet beet pulp contains considerable of other easily digested carbohydrates. Like roots, it should be fed with dry feeds. Most of the mineral matter is extracted from the beets along with the sugar and the pulp is also low in protein. Therefore, when heavy allowances of pulp are fed, one should see that the animals are supplied with sufficient mineral matter and protein. Fortunately, the pulp is commonly fed with legume hay, which is high in both protein and mineral matter.

Thousands of cattle and tens of thousands of sheep are annually fattened near the western beet-sugar factories on wet, soured, beet pulp, fed with alfalfa hay and a limited allowance of grain. The wet pulp is also excellent for dairy cows, producing good-flavored milk when not fed in excess. It may also be fed to idle horses.

Dried beet pulp.—Many beet-sugar factories are now equipped with machinery for drying the pulp. Dried beet pulp, which contains about 60 per ct. nitrogen-free extract, is worth nearly as much as corn or barley for dairy cows, beef cattle, or sheep. Since it is low in protein it should be fed, like corn, with protein-rich feeds.

Because dried beet pulp absorbs a great deal of water, it is advisable to moisten the dried pulp with 2 to 3 times its weight of water before feeding, when large amounts are used. Sometimes the moistened pulp is fed as a substitute for corn silage to dairy cows, tho usually the latter is more economical. Dried beet pulp is excellent for dairy cows on official test which are receiving a heavy concentrate allowance, as it is a bulky feed and also has a slightly laxative effect.

Beet molasses.—Molasses from beet-sugar factories, which contains about 66 per ct. nitrogen-free extract, nearly all sugar, is a valuable carbonaceous feed, if properly used. The feeding value of the molasses is about three-fourths that of corn. Both beet and cane molasses are low in crude protein, and the small amount present is of low nutritive value. Molasses should thus be used with protein-rich feeds. Because of its laxative nature animals should be gradually accustomed to this feed, and the amount given daily per 1,000 lbs. live weight should be limited as follows: Driving horses may be fed 2.5 lbs. and draft horses 4 lbs. or even more; dairy cows up to 3 lbs.; fattening cattle to 8 lbs.; fattening sheep to 5 lbs.; and fattening swine to 10 lbs. Breeding animals should receive less than fattening ones, and but little for some weeks before delivery. Because of its sticky nature, the molasses is usually distributed over hay or straw, and large feeders in the West use machines for mixing it with cut roughage.

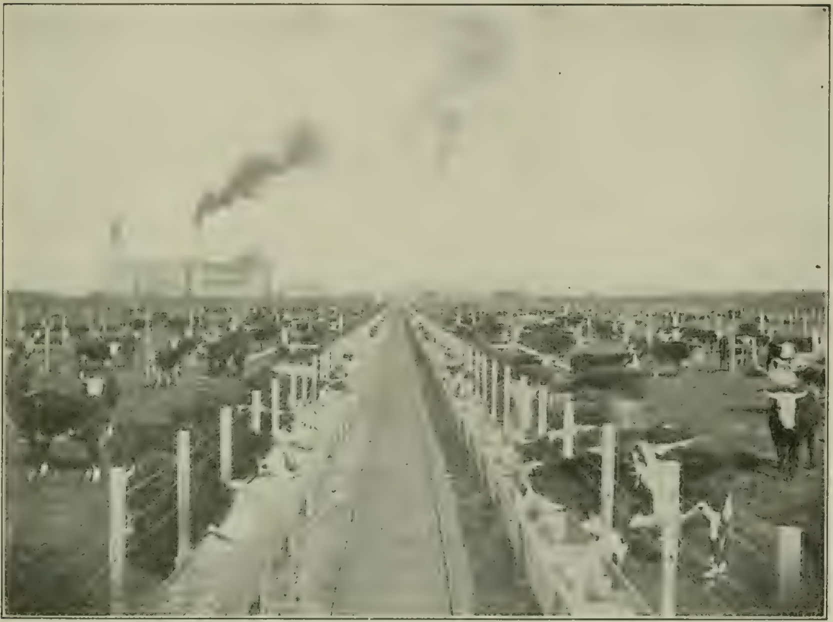

FIG. 44.—CATTLE FATTENING ON WET BEET PULP IN THE WEST

The beet pulp is brought to the feed lots on the tramway. Note the beet-sugar factory in the background.

Molasses-beet pulp.—Beet molasses is sometimes combined with beet pulp and dried, forming dried molasses-beet pulp. This feed is somewhat more palatable and digestible than ordinary dried pulp and has equal or slightly higher feeding value.

Beet tops.—Beet tops, consisting of the leaves and upper portion of the beet root, are often fed either fresh or ensiled to animals. They may be ensiled in pits or silos in alternate layers with straw, or mixed with cut dry corn fodder or stover. The leaves have about half the feeding value of roots. As they tend to purge the animals, they should be fed only in limited amounts and always with dry roughage. Kellner advises furnishing 3 ounces of chalk or ground limestone for every 100 lbs. of leaves, as otherwise the oxalic acid they contain may prove harmful.

Cane molasses.—Cane molasses, or blackstrap, a by-product of the manufacture of cane sugar, is much relished by farm animals and does not have the purging effect of beet molasses when fed in large amounts. In the South cane molasses is often one of the cheapest feeds and is extensively fed to horses, mules, and other animals. In the North it is sometimes so high priced that corn meal and similar feeds are more economical sources of carbohydrates. For improving unpalatable feeds, as a tonic for unthrifty animals, and as a colic preventive for horses, from 2 to 3 lbs. of molasses daily is helpful. Like beet molasses, blackstrap is largely used in mixed feeds.

Molasses feeds.—Molasses feeds consist of molasses combined with a wide variety of products, from high-protein feeds like cottonseed meal to such low-grade, trashy refuse as peanut hulls. Many contain screenings but these are now usually so finely ground as to destroy all weed seeds. Deception is easy in such feeds because the molasses masks the other ingredients and permits low-grade waste products to be sold at a price that should buy high-grade concentrates. If sold at prices which are reasonable as compared with the cost of equal amounts of nutrients in high-grade straight concentrates, nothing can be said against the use of reliable feeds of this class. They should be purchased only from trustworthy dealers and on definite guarantee of composition. Especial attention should be paid to the fiber guarantee, for this shows to what degree low-grade products have been used.

Molassine meal consists of molasses absorbed by sphagnum moss or peat. Peat has no nutritive value for farm animals and the moss but little. Almost the only nutriment is in the molasses, which can be purchased cheaper and mixed with better roughage on the farm.

Sugar.—Tho the nutritive value of sugar is no greater than that of starch, animals show great fondness for it and it is often useful for stimulating the appetite and in fitting animals for shows.

Dried distillers' grains.—In the manufacture of alcohol and distilled liquors from cereals, after being ground the corn, rye, etc., are treated with a solution of malt to change the starch to sugar, which is then changed to alcohol by the action of yeast. The alcohol is next distilled off leaving a watery residue known as *distillers' slops*. The solid matter from this is dried to form *dried distillers' grains,* which contain the portions of the grain not acted upon during the fermentations; that is, the crude protein, fiber, fat and the more insoluble carbohydrates. Distillers' grains from corn usually contain about 30 per ct. protein and rank between gluten feed and linseed or cottonseed meal in feeding value. Those from rye contain about 23 per ct. protein, and are thus of considerably lower value.

Because of their bulky nature and high nutritive value, dried distillers' grains are one of the best high-protein concentrates for dairy cows. Not being especially palatable, they should be mixed with better-liked feeds and the allowance restricted to 2 to 4 lbs. per head daily. Tho the grains are not relished by horses, they may form one-fourth the concentrate allowance. They serve well as part of the concentrates for fattening steers and sheep, but are too bulky for extensive feeding to pigs.

Salvage grain.—Grain damaged by fire, smoke, or water in warehouse fires is known as salvage grain. Its value depends on how much it is damaged and on the amount of screenings present.

Cocoa shells.—This by-product of the manufacture of cocoa and chocolate consists of the hard outside coating, or bran, of the cocoa bean. The shells, which are dark brown and brittle, are used in a few proprietary feeds. They are of low digestibility and worth not over half as much as corn meal.

Proprietary and mixed feeds.—There are now on the market a host of mixed feeds, chiefly sold under proprietary names. Their composition differs widely, some containing only high-grade concentrates like wheat bran, cottonseed meal, malt sprouts, gluten feed, etc. Others contain more or less screenings or light-weight grain, which will in general be of lower value than good-quality grain. Many of these feeds contain such low-grade by-products as oat hulls, ground corn cobs, flax plant by-product, etc., and some consist largely of such material. Altho the percentages of crude protein, fat, and fiber in any given brand are usually kept at the same figure from month to month, the amounts of the separate ingredients in the feed are seldom guaranteed. Thus the feed put out this year under a certain proprietary name may not be the same as that sold next year under the same name and guarantee. For this reason practically no trials to determine the values of these mixtures have been conducted by the experiment stations.

Many mixed feeds are the result of honest and intelligent efforts to furnish a ready-mixed "balanced" concentrate mixture for the various classes of farm animals. Such have won good reputations among intelligent feeders. Others are merely attempts to delude the purchaser into paying as much for mixtures of low-grade, trashy by-products as high-class concentrates would cost. All mixed feeds should be purchased not on the strength of a "fancy" name, but on the guarantee of the amounts of crude protein, fat, and fiber present in the mixture. By comparing the fiber guarantee with the fiber content of well-known unmixed concentrates, as given in Appendix Table I, one may estimate the extent to which such refuse as oat hulls and ground corn cobs have been added. Such materials, high in fiber, furnish little nutriment, tho they may give bulk to an otherwise heavy mixture. Before buying mixed feeds, the wise feeder will compare the amount of nutrients he can secure for each dollar in these feeds and in the unmixed standard by-products.

IV. Commercial Feeding Stuffs Control

Because it is often impossible for the stockman to tell from the appearance of a commercial feed whether it is of standard quality or has been adulterated, laws have been enacted to protect honest dealers and manufacturers and the users of commercial feeds alike.

Regulation of commercial feeds.—Many of the states now have laws which require that each package of concentrated feed bear a label, tag, or statement giving the percentages of crude protein and fat the feed contains. Some states wisely require that the maximum amount of fiber be guaranteed. (This means that the feed must not contain more fiber than the guarantee states.) In others all ingredients in mixed feeds must be stated.

Large users of commercial feeds are usually experienced buyers who purchase only the better grade of standard feeding stuffs at close prices, or secure such materials as screenings, etc., knowing fully their composition and value. It is the small buyer, often feeling the pinch of poverty, who is most easily ensnared by the extravagant claims and catchy names of the low-grade, trashy articles. In his attempt to secure something that sells for less than is demanded for standard goods, he forgets that these cheap commercial feeds are really more like roughages than concentrates, and roughages can be produced on most farms far more economically than they can be purchased in bags from the feed dealer. Low-grade feeding stuffs, no matter what their names, will bring hardship to the animals fed on them, and to the owners of such animals as well. When in doubt as to the merits of a feeding stuff, one should consult the feed control officials of his state, or buy only the pure, unmixed grains, straight milling or factory by-products, or high-grade proprietary feeds that have won good reputations.

A guide in purchasing commercial feeds.—Before purchasing commercial feeding stuffs, the guaranteed composition should be obtained and compared with the average composition given for the same feed in Appendix Table I. If the feed is much lower in crude protein or fat, or noticeably higher in fiber than there shown, it should be viewed with suspicion. The feed should also be free from mold and rancidity.

V. Condimental or Stock Foods

In spite of the advice of the experiment stations to the contrary, American farmers continue to spend millions of dollars for various proprietary articles called "stock foods," "condition powders," etc., which often cost 10 to 30 cents or more per pound.

Composition of stock foods.—The better class of stock foods have as their basis such substances as linseed meal or wheat middlings, while the cheaper ones contain ground screenings, low-grade milling offal, the ground bark of trees, etc. To this "filling," is added a small percentage of materials like common salt, charcoal, copperas, fenugreek, gentian, pepper, epsom salts, etc. Claims are made that a tablespoonful of the compound with each feed will cause stock to grow faster, fatten quicker, yield richer milk, etc., etc. Yet this amount supplies only an insignificant part of the dose of these drugs which is prescribed for ailing animals by competent veterinarians. Farm animals managed with reasonable care have appetites that do not need stimulating. Sick animals or those out of condition require specific treatment, not a cure-all. A good manager of livestock has no use for expensive conditioners and a poor one will never have fine stock by using them.

In rare cases some conditioner may be helpful in stimulating the appetite or otherwise improving the general thrift of the animal. To cover such cases the following formulae are given:

A formula recommended by Dr. F. B. Hadley of the Wisconsin Station is: Common salt, 280 lbs.; dried iron sulphate, 16 lbs.; powdered wood charcoal, 12 lbs.; and flowers of sulphur, 8 lbs. These materials should be well mixed or ground together to make a powder. This mixture, which it will be noted consists chiefly of common salt, should be kept in suitable boxes so that the animals may have free access to it.

Artificial Carlsbad salt has recently come into vogue among veterinarians as a conditioner, especially for horses. The formula for this is as follows: Dried sodium sulphate, 40 parts by weight; sodium bicarbonate, 35 parts; common salt, 15 parts; potassium sulphate, 2 parts. The ingredients should be mixed and powdered. For mature horses, 1 to 2 heaping tablespoonfuls should be given 2 or 3 times daily on the feed; and for mature cattle 1.5 to 3 heaping tablespoonfuls. The dose for swine or sheep is one-fifth as much as for horses. Half-grown animals should be given half as much as mature ones; younger animals one-eighth to one-fourth the full dose; and sucklings, one-sixteenth the full dose.

The flattering testimonials for many of the stock foods may be explained without granting any special virtue to the food. These foods are usually accompanied by directions which advocate liberal feeding and good care of animals getting the food in order to "secure the benefits of the tonic." Following this advice, the farmer feeds and cares for his stock better than ever before, and obtains better results. due not to the stock food, but to the directions which accompanied it. The wise feeder will not purchase advice along with costly condimental foods but will secure it in standard agricultural books and papers, or from the experiment stations and the United States Department of Agriculture.

QUESTIONS

1. Give the average composition of cow's milk and tell of the uses of skim milk, buttermilk, and whey in feeding.
2. Why should dairy by-products be pasteurized before feeding?
3. How is tankage produced and what are its uses for feeding?
4. Tell something about the other animal by-products fed to stock.
5. How is wet beet pulp obtained and what are the uses of both the wet and the dried beet pulp?
6. Discuss briefly the properties and value of both beet and cane molasses.
7. Tell how dried distillers' grains are produced and discuss their feeding value.
8. What have you learned about proprietary feeds?
9. What is meant by feeding stuffs control and what are its advantages to the stockman?
10. Would you buy stock foods? State your reasons.

CHAPTER XII

INDIAN CORN AND THE SORGHUMS FOR FORAGE

I. Indian Corn

Indian corn, the imperial agricultural plant of America, produces under favorable conditions from 10 to 25 tons of green forage per acre, containing from 4,000 to 10,000 lbs. of dry matter. When grown in a dense mass but little seed forms, and we have a rank grass which cures into a bright, nutritious, coarse hay. If the plants grow some distance apart, a large yield of grain results, with excellent forage as a secondary product. Were a seedsman to advertise Indian corn by a new name, recounting its actual merits while ingeniously concealing its identity, either his claims would be discredited or he would have an unlimited demand for the seed of this supposed novelty.

To fix in mind the manner in which corn grows and elaborates food for animals, before proceeding with the further study of this crop the student should review the study of an acre of corn given in Chapter I. The importance of corn as a cereal has already been discussed in Chapter IX.

Corn as a forage plant.—The entire fresh green corn plant may be fed as a soiling crop, it may be ensiled or cured as fodder corn, or the grain may be removed and the remaining stover used for feed. As shown later, ensiling is by far the most satisfactory means of preserving the entire crop as forage.

The term *corn fodder* or *fodder corn* is applied to corn plants, either fresh or cured, which have been grown primarily for forage, with all of the ears, if any, originally produced. *Shock corn* and *bundle corn* are terms used for fodder corn which carries much grain, but which is fed without husking. *Corn stover* is the term applied to cured shock corn from which the ears have been removed. The terms fodder and stover are also applied to such crops as the sorghums. For example, kafir forage is called either kafir fodder or kafir stover, depending on whether or not the heads have been removed.

Like the corn grain, corn forage is low in crude protein compared with carbohydrates and fat. As shown in Appendix Table III, the nutritive ratio of corn silage is 1:15.1, and that of fodder corn 1:15.7 to 1:17.1, while corn stover has the very wide nutritive ratio of 1:21.0 or over. Hence, these roughages should be supplemented by feeds rich in crude protein. Corn forage is fair in phosphorus and high in lime, compared with corn and the other cereal grains.

Thickness of planting.—How thick to plant corn for forage to secure the highest feeding value, has been studied at several experiment stations. The following table shows the results secured at the Illinois Station [1] where corn was planted on good prairie soil from 3 to 24 inches apart in the row, all rows being 3 feet 8 inches apart:

Results of planting corn kernels various distances apart in rows

Distance between kernels in row	Good ears per acre Bu.	Poor ears per acre Bu.	Stover per acre Tons	Total digestible nutrients per acre Lbs.	Stover for each lb. of corn Lbs.
3 inches	13	46	4.8	6,218	3.6
6 inches	37	39	3.7	5,980	1.9
9 inches	55	22	3.1	5,539	1.5
12 inches	73	16	3.0	5,593	1.3
15 inches	63	11	2.9	5,180	1.4
24 inches	49	6	2.5	4,207	1.5

With the kernels but 3 inches apart in the row there were 46 bushels of "nubbins," or poor ears, and only 13 bushels of sound ears per acre. However, this thick planting gave the largest returns in digestible nutrients—over 6,000 lbs. per acre, and there was the largest amount of stover for each pound of corn. The largest yield of sound ear corn was secured by planting the kernels 12 inches apart in the row, the returns being 73 bushels of sound and 16 bushels of poor ears per acre, with only 600 lbs. less digestible matter than from planting the kernels 4 times as thickly. These and other trials show that when corn is to be grown for forage, the seed should be planted so thickly that but few good ears form. If the chief object is grain, with stover secondary, the kernels should be planted at such a distance apart that all plants may produce full-sized ears. No general rule can be given as to the definite amount of seed to be planted per acre, for this varies greatly and is determined by local conditions. One should know accurately the capacity of his land for corn, and seed accordingly.

Nutrients in grain and stover.—Even when grown for the grain, a considerable part of the feeding value of the corn crop is in the stover. In trials at 4 northern stations [2] an average yield of 4,415 lbs. of ear corn and 3,838 lbs. of stover was secured per acre. The stover contained one-fourth of the digestible crude protein and over one-third of the total digestible nutrients in the crop. The amount of total digestible nutrients it contains measures the value of the stover for merely carrying animals thru the winter. For fattening animals, dairy cows producing heavy yields of milk, and horses at hard work, a more accurate measure of its value is the net energy it supplies. Yet, even on this basis the stover furnished one-fourth the net energy of the crop. This shows clearly the loss of animal food which occurs each year when unnumbered acres of corn stover are allowed to decay in the fields.

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[1] Hunt and Morrow, Ill. Bul. 13.

[2] Summarized by Armsby, Penn. Rpt. 1887.

Corn silage.—Indian corn is pre-eminently a silage plant. The solid, succulent stems and broad leaves when cut into short lengths pack closely and form a solid mass which not only keeps well but furnishes a product that is greatly relished by stock and is consumed with little waste. Altho with enlarging experience the use of other crops for silage is increasing rapidly, by far the greater portion of all the forage stored in silos in this country is corn. The use of corn silage has practically revolutionized the feeding of dairy cattle over a large part of the United States, and is fast becoming almost equally important in the feeding of beef cattle and sheep. Thru its

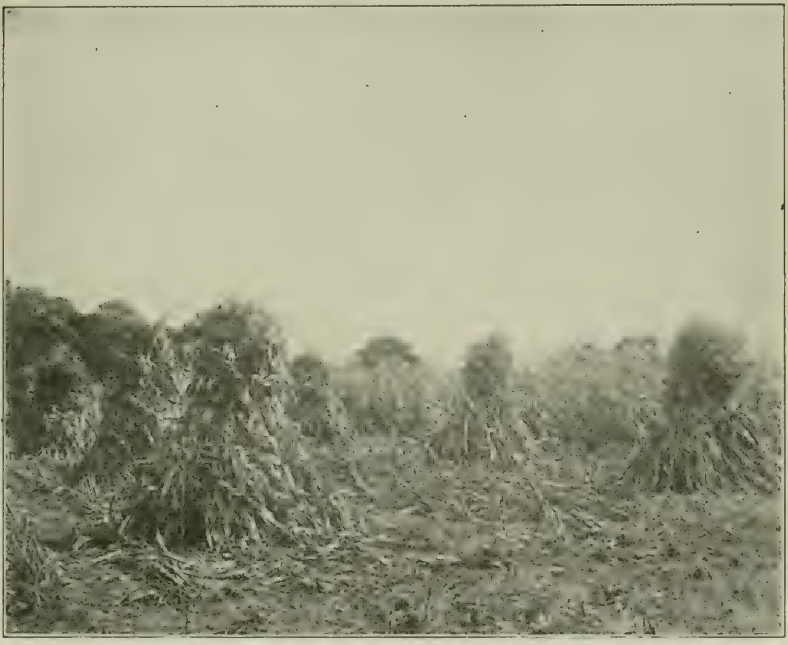

FIG. 45.—LARGE, WELL-MADE SHOCKS OF CORN LESSEN THE WASTAGE

To lessen the loss from weathering, corn fodder and stover should be placed in large, well-made shocks. Even then a greater loss usually occurs than when the corn is ensiled.

use the cost of producing milk and meat may be materially lowered all over the corn belt. Not only is corn silage excellent for cattle and sheep, but it may be used in a limited way with horses that are idle or at light work. The yield of silage per acre varies widely with the soil and season. A 50-bushel crop of corn should make from 8 to 10 tons of silage, depending on the size and leafiness of the stalks. The importance of corn silage on American farms and the methods of feeding it are discussed further in Chapter XVI and in the respective chapters of Part III.

Corn silage vs. corn fodder.—Ensiling is the best method of preserving corn forage, for less nutrients are lost than when the crop is cured as corn fodder, and corn silage also has a higher feeding value than the same amount of dry matter in cured corn fodder. Even when cured in well-made shocks, corn fodder or stover standing in the field for a few months loses at least 15 per ct. and usually nearer 20 per ct. of the dry matter it contains, due to weathering and to fermentations which gradually waste the forage. The losses fall chiefly on the most valuable parts of the plant—the protein, sugar, and starch—which are less resistant and more soluble than the fiber.

Losses also occur when corn fodder is ensiled, due to the fermentations which take place in the ensiling process. The extent of the losses will vary quite widely, depending on the stage of maturity of the corn when ensiled, the care with which the cut fodder is packed in the silo, the tightness of the silo walls and doors, and the depth of the silo. Considering all available data, we may conclude that in a silo 30 ft. deep or over, the total loss of dry matter should not be over 15 per ct., if reasonable care is taken to pack the silage and to reduce the losses at the surface of the silage after filling. The losses of dry matter are therefore about 5 per ct. lower when the corn crop is ensiled than when it is cured as dry fodder.

The feeding trials with dairy cows and steers reported in Part III show that silage gives better results than a corresponding amount of dry fodder. This is doubtless due to the fact that cattle usually reject the dry butts of the corn stalks, even when finely cut, while in silage they are eaten. Moreover, owing to the great palatability of this succulent feed, silage-fed animals consume a larger ration, and more nutrients are hence available for milk or flesh production after supplying the wants of the body. Just as important as these advantages is the fact that, like other succulent feeds, silage has a beneficial laxative effect, and is a valuable aid in keeping farm animals thrifty.

The corn for silage.—In earlier years corn was usually ensiled before the kernels were in the glazing stage. Experience has shown, however, that much sweeter silage is produced when corn is not ensiled until the kernels have hardened and glazed. (With the dent varieties when they are well dented.) The rapid storage of high-quality nutrients, pointed out in Chapter I, which takes place during the glazing stage and later, is an even more important reason for waiting until the corn is nearly mature. The crop should, however, be cut for silage while most of the leaves are yet green.

In the North the question arises as to whether to grow for silage the smaller northern varieties of corn, or the tall, late southern kinds which will not mature before frost. Trials have shown that these rank growing varieties will yield a larger amount of digestible nutrients per acre than the smaller ones, but such immature corn makes silage which is sour and contains but little grain. The stockman with plenty of hay, straw, and stover to feed will wish to fill his silo with a richer feed than the southern corn yields, and will therefore use northern dent or flint varieties which mature. To secure a large tonnage, he will plant the crop somewhat more thickly than for grain production, but yet so as to secure a relatively large proportion of grain to roughage. He will thus secure a rich silage which will materially reduce the amount of concentrates required for his stock.

In late seasons it is best to let corn stand till after frost rather than ensile it too green, for satisfactory silage can be made from frosted corn, and the crop may mature to a considerable extent before a severe frost comes. If the crop is killed by frost, it should be ensiled quickly, for the storm which usually soon follows will wash out much nutriment from the frosted forage, and the wind will soon whip off the dried, brittle leaves. If the plants dry out before all the crop can be ensiled, water should be added as the silo is filled to insure the necessary fermentations that preserve the silage.

Corn fodder or stover silage.—In recent years it has been found that silage can be made from cured corn or sorghum forage. When cut into the silo, thoroly moistened, and well-packed, it will undergo fermentation similar to that which occurs with green material, and will thus be preserved in a satisfactory manner. Tho usually less palatable than silage from green fodder, this product has an aromatic silage odor and is readily consumed by stock with less waste than is dry fodder or stover. This method is now followed by many farmers, especially in the plains region, some filling their silos three times a year—in the fall with green corn or sorghum, and later with the cured forage. It is necessary to add enough water so that the material will pack well and then to tramp it down with especial thoroness; otherwise the mass will spoil. Tho the water may be added to the cut material in the silo, it can be distributed more evenly if a stream is run into the blower, and then more water sprinkled over the cut fodder in the silo as it is filled. Due to the widely varying water content of field-cured corn forage, it is impossible to state definitely the amount of water to be added. Some recommend adding about an equal weight of water to the forage, others add just enough so that water may be squeezed out of the cut material.

Dry corn fodder.—Tho not as palatable and valuable as corn silage, corn grown thickly and cured as dry fodder while the leaves are yet green makes a coarse hay of high feeding value. Such fodder, with bright, nutritious leaves and small palatable ears that are easily masticated, has a value not as yet appreciated by most stockmen. Overlooking the splendid qualities of corn as a forage plant, too many farmers have become accustomed to growing this giant grass for the grain it yields, using the stover as a straw to be fed or wasted as accident determines.

As it is low in protein, corn fodder gives the best results when legume hay forms part of the roughage, such combination giving excellent results with dairy cows, beef cattle, and sheep. Corn fodder is also an economical substitute for timothy hay with idle horses, brood mares, and growing colts. Corn fodder and stover should be placed in large, well-made shocks, to reduce the losses by weathering. Since the stalks stand almost vertical in the shocks, as the leaves wilt there is ample room for the upward passage of air currents, which rapidly dry the interior and check molds and fermentations. When shock corn is pronounced ''dry'' by the farmer, it usually carries more water and consequently less dry matter than hay, a fact which should not be overlooked when feeding this forage. Care must be taken that corn fodder or stover is well-cured before it is stacked, and especially before it is stored in the mow, for musty, moldy forage is not only unpalatable but even dangerous. In districts of the South where it is exceedingly difficult to cure corn forage, the silo is particularly useful.

Shock corn.—Rather than husking corn and feeding the grain and stover separately, it is often more profitable to feed shock corn, the animals doing their own husking. This is especially true for animals which need only a small grain allowance, such as cattle being carried thru the winter and idle horses. Shock corn may also be successfully fed to fattening cattle and sheep, particularly at the beginning of the fattening period, and to a less extent to dairy cows. It is true that when fed unhusked some corn passes thru the animal unbroken, but feeding trials show that, despite such waste, there is often little or no profit in husking the ear and reducing it to meal. A little study will determine the amount of grain the shocks carry, so that the feeder can properly adjust the proportion of grain to roughage by supplying either ear corn or corn stover, as the animals may require.

Corn stover.—The forage which remains after removing the ears from shock corn has a higher feeding value than is usually believed. Stover produced in the northern portion of the corn belt is superior in nutriment and palatability to that grown in the South. As soon as fairly well cured, stover should be placed under cover or stacked, rather than left to waste away in the field. When fed with alfalfa or clover hay, good corn stover may often profitably form half the roughage allowance for fattening cattle or sheep. For stock cattle and breeding cows it may be utilized to even a larger extent, and it is also satisfactory for breeding ewes. While corn stover alone will not quite maintain the weight of growing steers during the winter, stover and legume hay with no grain will make fair gains. This cheap feed is also a satisfactory roughage for horses doing but little work. Most of the roughage of dairy cows should be more palatable and nutritious in character, but corn stover may often be economically fed even to them.

Shredding or cutting stover or fodder.—When shock corn is husked by machinery, the stover is usually cut or shredded at the same operation. Corn fodder is also often passed thru a feed cutter before feeding. This finer material is no more digestible than the uncut forage. However, cutting or shredding usually reduces the waste, as it induces the cattle to eat a greater part of the stalks, unless they are coarse and woody. The cut or shredded forage is also easier to handle, and the waste is in better shape for bedding.

Corn for soilage.—Corn ranks high as a soiling crop on account of its palatability, the high yield of nutrients, and the fact that it remains in good condition for feeding for a much longer period than many other crops grown for soilage. On farms lacking summer silage, feeding corn forage in the green stage as soilage should become general, for during the late summer and early fall pastures are often too scanty to enable animals to do their best. In the case of dairy cows such a shortage of feed will cause a decrease in milk flow, which often cannot be recovered by subsequent liberal feeding. An acre of ripening corn fed in early fall may return twice as much profit as if it were held over until winter. For early feeding sweet corn may often be advantageously used.

II. The Sorghums

In the dry-farming districts, from Nebraska to Texas and Arizona, the sorghums, both the saccharine *sorghos* and the non-saccharine *grain sorghums*, are of great and increasing importance as forage crops, because they are far more drought resistant than corn and the leaves remain green late in autumn. The sorghums, mainly the sorghos, are valuable in the southern states for hay, soilage, and silage, and are also grown in the northern states, chiefly for soilage.

Three tons of air-dry fodder is a good and 6 tons a large return from the sorghums, while maximum yields may reach 10 tons of dry fodder or 40 tons of green material.[3] Under Kansas conditions the sorghums produce one-third to one-half more forage per acre than corn.[4]

FIG. 46.—A FIELD OF KAFIR IN THE TEXAS PANHANDLE

Because of their resistance to drought, the grain sorghums and the sorghos are of great importance as forage crops in the semi-arid districts. (From *The Southwest Trail*, Rock Island Lines.)

Sorghum fodder and stover.—Thruout regions of scanty rainfall the sorghums are most commonly grown in drilled rows of sufficient width to allow cultivation, by which the moisture is conserved and larger yields obtained. When grown in drills, not too thickly, much seed is produced and the stalks are somewhat coarse. Sorghum forage is more palatable when cut before full maturity, but the seed should be allowed to reach the early dough stage, for if cut earlier the plants

[3] Piper, Forage Plants, p. 269.

[4] Reed, Kan. Cir. 28.

are watery and contain little nutriment. The crop is cured in shocks, the same as Indian corn, but in the case of the juicy-stemmed sorghos, which cure with difficulty, the shocks should be small. In sections with ample rainfall the seed is often broadcasted, and the fine-stemmed plants cut and cured the same as the meadow grasses. In the South where the rainfall is ample and on irrigated lands 2 to 3 cuttings of sorghum may be secured in the season, if the crop is cut before it matures; in the dry-farming districts it is usually cut but once.

The various types of grain sorghums have been described in Chapter X. The kafirs excel in yield and value of forage, for they are leafy and the stems are more succulent than those of milo, feterita, or kaoliang. Kafir fodder and stover compare favorably in composition and feeding value with that from corn. Feterita ranks next to kafir for forage, while milo, kaoliang, and shallu are less leafy and have more pithy stems. The dwarf types of the grain sorghums are often harvested with a grain header, and stock grazed on the standing stalks.

The sorghos, with their juicy stalks rich in sugar, are grown chiefly for forage. Early varieties, such as Amber cane, ripen earlier than kafir or milo, and may be grown wherever corn will mature. The palatable leaves, sweet stalks, and freedom from dust make sorgho forage a desirable roughage for stock, especially horses.

The sorghums for grazing, soilage, and silage.—Especially in the southern states, the sorghums, mainly the sorghos, are widely used as summer pasture for horses, cattle, and swine, since they are available at a time when other crops are exhausted or immature. Owing to the danger from prussic acid poisoning, extreme care must be taken in pasturing second growth or stunted sorghums. By feeding the green crop as soilage it is utilized more completely than when pastured. Tho sorghum may be cut at any time after it reaches a height of 2 to 3 feet, a greater yield of nutrients will be secured when it is allowed to head. The early varieties of sorghos are admirable soiling crops for the northern states.

The sorghums formerly had the reputation of producing much sourer silage than corn. However, numerous experiments have now shown that when sufficiently matured both the sorghos and the grain sorghums make excellent silage. To determine when cane or kafir is ready to ensile twist a stalk with the hands. When it is so mature that only a little juice will run out the proper stage has been reached.[5] As with corn, it is preferable to let the crop of cane or kafir stand till after frost, rather than ensile when too green. The bagasse or waste of the sorghum syrup factories should not be wasted, but may be satisfactorily ensiled, as may the leaves removed before running the stalks thru the mill.

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[5] Reed, Kan. Cir. 28.

QUESTIONS

1. Define corn fodder, shock corn, and corn stover.
2. What is the effect of thickness of planting corn on the yield of ears, stover, and total nutrients?
3. What part of the digestible crude protein, total digestible nutrients, and net energy of a corn crop grown for grain is in the stover?
4. Discuss corn as a silage crop and compare corn silage with corn fodder.
5. How should the corn crop be handled for silage so as to secure the best returns?
6. How is silage made from dry corn fodder?
7. Discuss the value of dry corn fodder and state how it should be preserved.
8. Under what conditions should corn be fed for soilage?
9. Discuss the value of forage from kafir, feterita, milo, and sorgho.
10 .What is the value of the sorghums for grazing, soilage and silage?

CHAPTER XIII

THE SMALLER GRASSES—STRAW—HAY-MAKING

I. The Smaller Grasses

Unlike the great grain-bearing grasses—corn, wheat, rye, barley, oats, rice, and the sorghums, which are all annuals—the smaller grasses are nearly all perennials. Hence they thrive without cultivation, producing roughage of good quality with little expense for labor. For building up the soil by adding humus and binding it together the smaller grasses are also of great importance. In summertime in regions where the smaller grasses flourish the animals of the farm largely feed themselves, and meat, milk, and wool are produced at the minimum expense.

The smaller grasses are divided into two classes—the sod-formers and the non-sod-formers. The sod-formers, which spread by creeping rootstalks, either above or below ground, making a smooth turf, include our most valuable pasture and lawn grasses, such as Kentucky bluegrass and Bermuda grass. The non-sod-formers, such as orchard grass, grow in tufts or bunches and increase only by seed or stooling, except in the case of a few, such as timothy, which also increase to some extent by forming new bulbs at the base of the stems.

Nutrients in grasses at different stages.—Few stockmen realize the great difference in composition between young, immature grass and the same grass as it is usually cut for hay. The Kentucky Station found that bluegrass, rye, wheat, and oats cut when only 5 to 8 inches high contained as high a percentage of protein as green alfalfa or clover. This shows that immature grasses, such as are gathered by grazing animals, are protein-rich feeds and explains the favorable results secured by feeding only corn, a highly carbonaceous feed, to fattening animals at pasture. On the other hand, when cut for hay, the smaller grasses are relatively low in protein compared with carbohydrates and fat, and hence hay from the grasses should always be fed with feeds rich in protein. Tho immature grass is richer in protein, a larger yield of dry matter and a larger total amount of protein is secured if the grass is not cut until nearly mature. Thus, when grass is cut for hay at the usual stage, more feed is usually secured per acre than if the same field were grazed by stock.

Bluegrass.—Kentucky bluegrass, or June grass, easily ranks first for lawn and pasture in the northeastern United States. By its persistence it often even drives out other grasses and clovers from the meadows and pastures. The fact that bluegrass is one of the richest of grasses in digestible protein helps explain the fondness for it shown by stock. Differing from most grasses of the humid regions, mature dried bluegrass is quite readily grazed by animals, thus resembling some of the grasses of the western ranges.

With the coming of spring, bluegrass pushes forward so vigorously that early in May the fields bear a thick, nutritious carpet of green. With seed bearing, the plant's energies become exhausted, and bluegrass enters a period of rest which lasts several weeks, and if a midsummer drought occurs the plants turn brown and appear to be dying. However, they quickly revive with the coming of the fall rains, and each plant is once more busy gathering nourishment for the coming season's seed bearing. The observant stockman soon learns the folly of relying on bluegrass pasture for a steady and uniform feed supply for his cattle thruout the season. Accordingly, he understocks the pasture in spring so that the excess of herbage during May and June

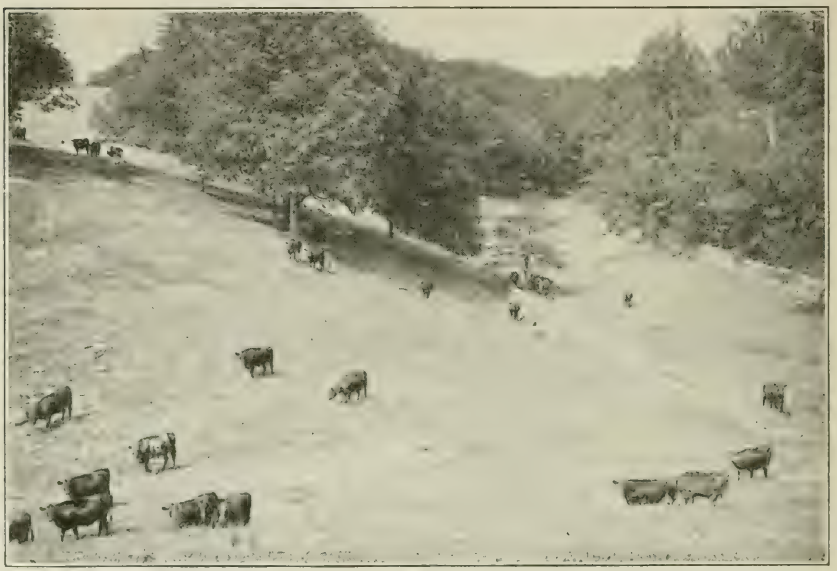

FIG. 47.—BEEF CATTLE FATTENING ON BLUEGRASS PASTURE

In the northeastern United States, Kentucky bluegrass is by far the most important pasture grass.

may remain to be drawn upon during the mid-summer dormant period, or he fully stocks it and makes up the later shortage by supplying silage or soilage. Because of its low, carpet-like growth, bluegrass is primarily a pasture, rather than a hay grass.

Timothy.—The acreage of timothy in the United States nearly equals that of all other cultivated hay plants combined, including clover and alfalfa. This cool-weather grass is of especial importance in the northeastern states, where it furnishes probably three-fourths of all hay marketed in the cities. The popularity of timothy is due to the following points: The seed is cheap and generally of good quality. A field of timothy is quickly established and usually holds well. The grass seldom lodges, may be harvested over a longer period than most grasses, and is easily cured into bright, clean hay which is quite free from dust and can be handled with little waste.

For horses timothy hay is the standard roughage, being preferred especially by city buyers. However, mixed clover and timothy hay, or even legume hay alone, if of good quality, may be successfully used in place of timothy. For dairy and beef cattle and for sheep timothy is greatly inferior to hay from the legumes, for timothy is low in protein and is also not so well-liked by these animals as is clover or alfalfa. Moreover, the yield of timothy is not large, for it produces but little aftermath. Therefore, on most farms where timothy is now extensively grown, greater use should be made of the legumes, which not only yield more hay, but at the same time increase the fertility of the land. Red or alsike clover should always be sown with timothy, except when the hay is to be grown for sale and the demand is for pure timothy, for the combination furnishes more and superior hay, even for horses. Grown together, the hay of the first season will consist largely of clover. With the close of the second season most of the clover disappears and the decaying clover roots nourish the timothy which remains, so that a much larger yield of that grass is obtained. Fodder corn and hay from the cereals—oats, wheat, or barley—are economical substitutes for timothy hay in many cases.

When to cut timothy.—In trials during 3 seasons at the Missouri Station[1] cutting timothy when the seed had just formed gave the largest yield of dry matter, closely followed by cutting when the seed was in the dough. However, when the hay was cut later than full bloom it was less digestible, and therefore the yield of digestible nutrients was greatest when the crop was cut at full bloom. After this the yield of both digestible protein and carbohydrates fell off markedly. This decrease in total digestible nutrients as the hay matures, which is opposite to what occurs in the corn crop, is due to the partial loss of the lower leaves as the plants ripen, to leaching by rain, and to the storage of nutrients in the bulbs at the base of the stems. In maturing corn the nutrients are stored in the kernels, which are easily masticated and highly digestible. In the smaller grasses, tho a similar storage occurs in the seeds, they are so small and have such hard seed coats that they escape mastication and their nutrients are largely lost.

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[1] Waters and Schweitzer, Proc. Soc. Prom. Agr. Sci., 1910, pp. 71–98.

Based on the yield of digestible nutrients alone, full bloom appears the best time to cut timothy for hay, but other factors must be considered. Such immature grass is difficult to cure, the weather early in the season is usually more unsettled, and the ground cooler. Also, haying must often be delayed in the corn belt until the corn has been cultivated. In general, timothy should be cut early for dairy cows, young stock, and sheep, since these animals do not relish hay that is woody and lacks aroma, as does most late-cut hay. For horses and fattening cattle late cutting is favored, since these animals get much of their nourishment from concentrates, and the hay they eat serves more as "filling." In any event, cutting should not be delayed until the grass becomes tough and woody and the seeds shatter.

FIG. 48.—CUTTING A FINE FIELD OF TIMOTHY

On most farms where timothy is now extensively grown, greater use should be made of the legumes, which not only yield more hay, but also increase the fertility of the land.

Red top.—This grass is probably suited to a wider range of climatic and soil conditions than any other cultivated grass. A couple of years after seeding it forms a close, well-knit, smooth sod, almost as dense as bluegrass turf. There is no better grass for marshy and damp lands, and at the same time it will withstand considerable drought. It endures on poor uplands and on soils too acid for most other grasses. Tho not so well liked as bluegrass, red top gives good pasture and yields a fine-stemmed hay, rated somewhat below timothy in value.

Orchard grass.—Tho it does well in full sunlight, this grass thrives better than most others in partial shade. It endures hot weather better than timothy and is well suited to the southern border of the timothy belt. As it starts early in the spring, endures drought well, and continues growth late in the fall, it furnishes valuable pasturage, tho stock prefer bluegrass. While late-cut orchard grass makes harsh, woody hay, that cut in early bloom is equal to the best of the hay grasses. Orchard grass grows in tufts, forming an uneven sod, and hence should be sown with clovers or other grasses, both for hay and pasture. Ripening two weeks before timothy, it fits in well with red clover.

Brome grass.—In that part of the great plains region stretching from South Dakota to Saskatchewan, brome is the most important cultivated grass. It furnishes good crops of hay, fully equal to timothy in feeding value, for three or four years after seeding, by which time it usually becomes sod bound and should be renewed by harrowing or shallow plowing. Brome is one of the most palatable of pasture grasses and endures heavy grazing. Tho the most drought-resistant of the cultivated grasses, brome is usually less productive than the native prairie grasses in the drier parts of the dry-farming belt.

The millets.—The millets are rapid growing hot-weather annuals of many races and varieties. Of these, the *foxtail millets* are the type most grown for forage in the United States. In this group are *common millet*, the earliest and most drought-resistant; the less drought-resistant, shorter stemmed *Hungarian millet*, the seeds of which are mostly purplish; and *German millet*, late maturing and with nodding heads, which yields more hay, but not of quite such good quality. The foxtail millets are especially valuable as hay crops on dry-farms in the northern plains region. In the more humid regions they are grown chiefly as catch crops. Millet should be seeded thickly for hay and should be cut as soon as the blossoms appear. Such hay is useful for cattle and sheep feeding, tho usually less palatable and inferior in feeding value to timothy hay or even bright, fine corn or sorghum fodder. Since millet hay is sometimes injurious to horses, it should be fed sparingly.

Japanese barnyard millet, a close relative of the common barnyard grass, has often been advertised as "billion dollar grass." Tho yielding large crops of coarse forage under favorable conditions, it is usually inferior to the foxtail millets for hay, and to corn for soilage. The *broom-corn millets*, previously described, are grown chiefly for seed production, as the yield of forage is low and the stems woody. *Pearl millet*, also called pencillaria or cat-tail millet, is adapted to the same conditions as the sorghums, which have proven more valuable and have largely displaced it in both the semi-arid regions and the South. As a soiling crop this tall growing grass has value in the southern states, yielding three or more cuttings in a season. It should be cut when 3 to 4 feet high, before the stems become hard.

Teosinte, a giant millet resembling sorghum, requires a rich, moist soil and is too tropical to have value north of the southern portion of the Gulf states. The culture of this grass is decreasing in the United States, because on moderately fertile soils it yields less than sorghum, and on rich land less than Japanese cane.

Cereal grains for forage.—All the small grains are suitable for hay, soilage, and pasturage. Over four million acres of small grains were cut for hay in 1909, half of this area being in the Pacific coast states. More than 40 per ct. of the hay grown in the southeastern coast states is from the small grains. Cereals should be cut for hay when the grains are in the early milk stage, and the bearded grains before the awns harden.

In the North fall-sown rye or wheat furnishes excellent late fall and early spring pasture and soilage, while spring-sown oats or barley provide green forage in early summer. Barley, being more rust resistant, is the best cereal grass for late summer seeding. In the South fall-sown grains may be pastured moderately thru the winter and will still yield considerable hay or grain. Green rye gives a bad flavor to milk unless the cows are pastured on it for but two or three hours after milking. A field sown to rye, wheat, oats, or barley for temporary pasture may be changed to a permanent one by sowing clover and grass seed thereon early in spring. The grass and clover plants will then begin growth under shelter of the young grain. Stock may graze on the cereal plants regardless of the young grasses and clovers but should be kept off the fields after rains. As the cereal plants gradually die, the grasses and clovers spread until they form a dense, permanent sod.

If ensiled when the kernels are just past the milk stage or slightly earlier, the cereals make fair to good silage. The crop should be run thru a silage cutter and unusual care taken in tramping down the mass to force the air out of the hollow stems.

Bermuda grass.—This low-growing, creeping grass is to the cotton belt what bluegrass and timothy combined are to the northeastern states. Bermuda forms a dense sod and serves best when closely grazed, as otherwise it becomes tough and wiry. It drives out most other grasses, but lespedeza or white clover will flourish in spots and improve the pasture. It furnishes pasturage from April to October and in winter, when it is dormant, the sod may be seeded with bur clover, hairy vetch, or Italian rye grass. Tho primarily a pasture plant, on rich soil Bermuda yields from three to four tons per acre of hay equal to timothy in value, tho the average is not over one ton.

Johnson grass.—In the South this plant is the worst weed of the cotton planter and yet the best meadow grass for many sections. Its vigorous creeping rootstalks make it difficult to eradicate when once established and it is therefore not usually sown on clean fields. From two to three tons per acre is the average yield of Johnson grass cut for hay, but 6 tons per acre has been reported. It should be cut before maturity. Tho too coarse for pasture, Johnson grass may be cut once a month during the summer for soilage.

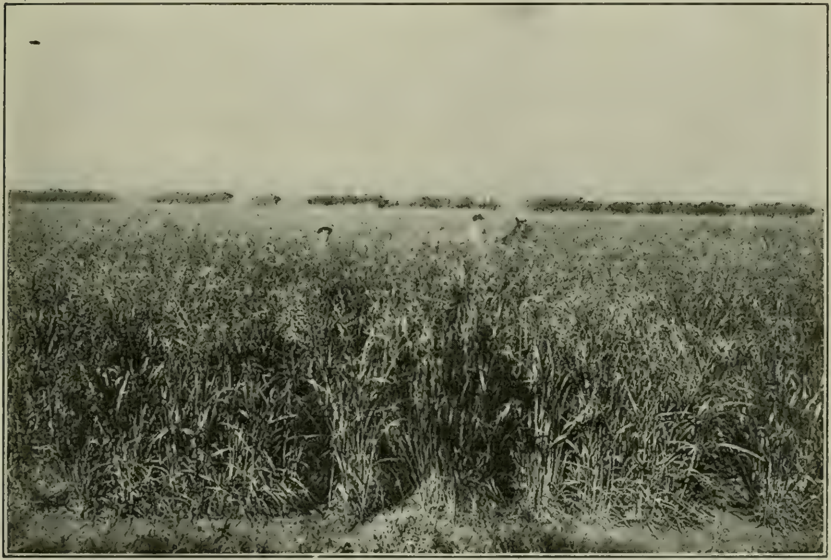

FIG. 49.—SUDAN GRASS—A NEW CROP OF MUCH PROMISE

This close relative of the sorghums is giving excellent results as a hay crop in the semi-arid districts and may prove superior to the millets as a catch crop in the northern states. (From U. S. Department of Agriculture.)

Sudan grass.—This close relative of the sorghums was introduced into this country by the United States Department of Agriculture in 1909. It closely resembles Johnson grass, but fortunately has no creeping rootstalks, and thus cannot become a pest. Tho a tall, rank-growing grass, the stems are comparatively slender, seldom being larger than a lead pencil. It yields hay similar to timothy in composition and somewhat superior to millet in feeding value. It gives one cutting in the northern states and two or more in the South. Being drought resistant and adapted to the same conditions as the sorghums, it is an important forage crop for the western portion of the plains region. As it is a heat loving plant, Sudan grass does not flourish at high altitudes or in the extreme North. Neither does it thrive along the humid Gulf coast. Yields of 1.25 to 5 tons of hay per acre have been secured in the great plains district, even with unusually severe drought, and under irrigation in the Southwest yields of 8 to nearly 10 tons have been obtained. Sudan grass is also a valuable soilage crop.

Japanese cane; sugar cane.—Because of its heavy yields, Japanese cane, a slender stemmed variety of the common sugar cane, is one of the cheapest forage crops that can be grown in the Gulf states, and possibly in southern California. In Florida it furnishes good pasture for cattle and hogs from November to March, but is killed by grazing after growth starts in the spring. The crop may be cured as dry fodder and makes good silage. Yields of 12 to 25 tons of green forage per acre are not unusual.

The tops and leaves of common sugar cane, removed on harvesting the cane, make satisfactory forage for live stock, and may be ensiled. It is a wasteful practice not to utilize this by-product by feeding to stock.

Wild and marsh grasses.—Along parts of the Atlantic coast are extensive salt marshes, the best of which are cut for hay at low tide, yielding 0.5 to 1 ton per acre. Such hay is from 10 to 18 per ct. less valuable than average mixed hay from the cultivated grasses for dairy cows. In all humid regions of the country are fresh water marshes, some of which are covered with the more nutritious true grasses, while in others the rushes and sedges predominate. Such marsh hay as blue joint, cut before maturity, nearly equals timothy in value. The prairies of the Great Plains and the grazing ranges of the West support numerous native grasses that furnish excellent pasturage and hay equal to timothy.

Mixed grasses.—No matter how valuable a single variety of grass may be, it should never be grown alone in permanent meadows and pastures, but always in combination with other grasses and the clovers. In the North an excellent combination is timothy, red top, and orchard grass, with alsike and medium red clover. The variety and proportion of grasses and clovers to be included in any mixture depend on climatic and soil conditions. Before sowing, one should consult the experiment station of his state, as well as observe what varieties of grasses and clovers thrive best in his particular locality.

The abuse of pasturage.—Too many stockmen rely entirely upon pastures for the maintenance of their cattle during half the year, not realizing that if drought prevails during the summer months the animals may suffer from hunger. In addition, there is the heat of "dog days" and the ever-present annoyance of blood-sucking flies. Stockmen who turn their cattle to pasture in spring, allowing them to forage as best they can until winter, are guilty of barbarism as truly as were the early Britons, who forced their stock to live on natural herbage not only in summer but in winter as well. If the animals died from starvation it was "an act of God." The stockman of today amply provides for winter's rigor, but he can never expect his flocks and herds to yield their best returns unless he also makes ample provision against the possibility of drought-ruined pastures in summer.

In America we have not begun to use our pastures as efficiently as is done in Europe, where stock is still economically grazed on land worth several hundred dollars an acre. By proper fertilization, reseeding, and keeping down of brush and weeds, the productivity of pastures may be greatly increased. In humid regions unless grasses are pastured so closely as to be killed out thru tramping, heavy grazing is often better than pasturing too lightly, for weeds are then kept from encroaching on the grasses.

Because of over-stocking and consequent over-grazing under the system of free grazing, the carrying capacity of many of the western ranges has been seriously reduced. The day of the "all-year-round" open range is almost past, and in its place has come a system under which, by the use of supplemental feed for periods of summer drought and winter storm, the natural forage is used much more wisely than before. With ranges thus handled, the enormous losses of cattle and sheep from starvation, which were all too common in the old range days, are prevented. Fencing or otherwise restricting the range, developing convenient water supplies, protecting the range during periods of seed ripening and germination, and preventing soil erosion, will greatly increase the amount of feed produced. In one instance a range of 25 square miles, 6 years after fencing, not only carried twice as many cattle as before but also kept them in much better condition.[2]

[2] Thornber and Griffith, Ariz. Bul. 65.

II. STRAW AND CHAFF

As plants mature, the nutrients which have been built up in the green portions are in large part transferred and stored in the ripening seed, thus largely exhausting the stems and leaves of easily digested nutrients and leaving in them the resistant woody fiber, or cellulose. All straws are, therefore, worth much less than the same plants cut for hay before maturity. The feeding value of each class of straw may differ widely, depending on the stage at which the crop was cut, the care with which it was cured, and the amount of the more nutritious grasses and weeds present.

Straw and chaff of the cereals.—Being low in protein, nitrogen-free extract, and fat, and high in fiber, straw furnishes less digestible nutrients and much less net energy than good hay. Accordingly, it should not form any large part of the roughage for animals at hard work, fattening rapidly, or giving a large flow of milk. On the other hand, a considerable portion of the roughage for idle horses and animals being carried over winter without gaining materially in weight may consist of straw. When much straw is fed, the additional protein needed should be supplied in other feeds. Growing steers, wintered on good straw as the only roughage, with 1 or 2 lbs. of cottonseed meal per head daily, will more than maintain their weight. A small amount of straw satisfies the desire for dry roughage of steers fattening on corn silage, corn, and cottonseed meal just as well as will clover hay.

In Canada and Europe pulped roots and meal are often mixed with cut or chaffed oat straw, and the moist mass allowed to soften. It is then readily consumed by cattle and sheep. In many districts of Europe horses are fed cut straw mixed with their concentrate allowance, small amounts being thus utilized even for horses at hard work.

Oat straw with its soft, pliable stems is the most nutritious, followed by barley straw. Wheat straw, being coarse and stiff, is not so readily eaten, and rye straw, harsh and woody, had better be used for bedding. The chaff of wheat and oats contains more crude protein than does the straw, and is a useful roughage when not loaded with dust, rust, or mold.

Straw from legumes and other plants.—*Straw from the legumes* contains more crude protein and less fiber than that from the cereals, and is more digestible. *Field pea straw*, with its fine stems and often carrying some seed, has a higher value than the coarser straw from field beans or soybeans, tho even these are better than oat straw if well cured. Clover straw may be fed to cattle or sheep, but is too dusty for horses.

While not especially desirable, *flax straw* may be fed in the absence of better roughage. The statement that the stringy fiber of flax forms indigestible balls in the stomachs of farm animals is unwarranted, since it is digested the same as other fibrous matter. Green-colored straw from immature flax plants should be fed with extreme caution, as it may contain enough prussic acid to be poisonous. *Buckwheat straw* has little value, and may cause digestive disturbances if fed in large amount. Properly cured *rice straw* is excellent for stock.

III. Hay-Making

Converting green forage into hay was probably the first step in changing the wandering herdsman into the farmer-stockman. To-day over seventy million tons of hay are produced annually in the United States, and thruout the temperate zone hay is the common roughage for all the larger animals of the farm.

Nutritive value of dried grass.—Trials have shown that grass dried under perfect conditions has as high nutritive value as when fed in the fresh state. However, in actual haymaking more or less of the nutrients are always lost, due to loss of leaves and exposure to sunlight, dew, and rain. Meadow hay exposed to prolonged rain may lose as much as 18 per ct. of the total dry matter, and legume hay still more. In a trial at the Colorado Station [3] alfalfa hay exposed to 3 rains, aggregating 1.8 inches, lost 31.7 per ct. of the total dry matter. The actual damage was even greater than this, for, while practically all of the fiber remained, 60 per ct. of the crude protein, 41 per ct. of the nitrogen-free extract, and 33 per ct. of the fat was lost.

Hay-making.—The ends sought in making hay are to reduce the water content to about 15 per ct., so that the hay will keep when placed in the stack or mow, and yet to secure bright green color, good aroma, and freedom from dust, and to retain the leaves and other finer parts, which, especially with legumes, easily fall off. During the process fermentations produced by enzymes occur, which develop a characteristic aroma.

A good but rather expensive method of securing prime hay is to mow the grass as soon as the dew is off, allow it to lie in the swath until dry on the surface, then turn by hand or tedder, or rake into loose windrows. Before the dew falls make into cocks, and, if dry enough so that it will not mold, allow it to remain in the cock till it has passed thru the "sweat." With legumes it is well to protect the cocks from rain by hay caps. After the sweat, open the cocks in large flakes. The hay will then soon dry out enough to be hauled to the barn or stack. Where the grass is green or damp when cocked, it may be

[3] Headden, Colo. Bul. 111.

necessary to open the cocks the next morning to avoid molding, and then recock the hay toward night, if not yet dry enough to store.

By this system the curing grass is exposed but little to the bleaching action of the sun and dew, and there is no marked loss of aroma, which, tho unweighable, has real value in rendering hay palatable. Before the partly dried plants are piled into cocks, the leaves will have dried out more than the stems. As the leaves and stems remain alive for some time after the grass has been cut, if the material is cocked before the leaves are entirely dried out and thereby killed, they will continue to draw water from the stems. Partially curing in the cock is especially important with the legumes, which usually have thick, succulent stems that dry slowly, while the leaves dry rapidly, and become brittle and shatter badly. Partially cured grass cocked in the afternoon entraps much warm air, which helps to continue the giving off of moisture during the night.

Hay put into the barn when so dry that it will not pack well, is not in first class condition. It should be mowed away with just that amount of moisture which allows it to settle compactly when trodden down. Salt and lime scattered over damp hay when put into the mow tend to prevent fermentation and check the growth of molds. Damp hay may also be improved by placing it in alternate layers with dry straw, which absorbs moisture as well as aroma from the hay, so that cattle the more readily eat both straw and hay. New-made hay, which is laxative and may cause colic in horses, should not be fed until the sweat in the mow is over and it has cooled off.

Making hay on a large scale.—Where large acreages of hay are made, it is often unprofitable to cure the crop in cocks, owing to the extra labor, even tho better hay is secured. Frequently the crop is mown in the morning and by frequent tedding and turning it is housed before the dew falls at night. In favorable weather even clover and alfalfa, when dry on the surface of the swath, are often raked directly into small windrows by a side-delivery or other rake, without previous tedding. After curing here for a few hours, the hay is loaded from the swath by the hay loader, or in the West is hauled to the stack with a sweep rake.

Another method is to cut the crop late in the afternoon so that the dew will not materially affect the plants during the night, because they are but little wilted. Even should rain come it will cause far less injury than if the plants were partially cured. The following day, by aid of tedder or rake the drying is hastened and the hay placed under cover or stacked before night.

When these methods are followed with the legumes, it is impossible to avoid much loss of the leaves, by far the most valuable part of the plant, for when curing in the swath or windrow the leaves become dry and brittle long before the stems are dry enough to allow the hay to be stored. When clover or alfalfa hay is carelessly made and allowed to become too dry most of the leaves may be lost, carrying a large part of the feeding value of the crop. To avoid this the wilted material should be raked into windrows before it has cured too much in the swath.

Measurement and shrinkage.—In computing the amount of hay in a mow, it is commonly assumed that after settling 420 cubic feet of timothy or 500 of clover hay equals 1 ton. To find the amount of hay in a stack, the following rule may be used:[4]

> Multiply the width of the stack in feet by the "over" (*i.e.*, the distance from the base on one side of the stack over the stack and to the base on the other side), divide the product by 4, and multiply the quotient by the length. This gives the contents of the stack in cubic feet. To find the number of tons for hay that has stood for less than 30 days, divide by 512; for 30 to 60 days, by 422; over 60 days, by 380.

Hay stored in the mow will shrink in weight, due to drying out, and also to fermentations taking place during the sweating process, in which nutrients are broken down into carbon dioxid and water. The shrinkage will vary, depending on the water content of the hay when placed in the mow, and may reach 20 per ct. or over. When hay is stacked, the shrinkage is greater, since the outside of the stack is exposed to the weather. A stack 12 feet in diameter has about one-third of its contents in the surface foot.

QUESTIONS

1. When does grass contain the largest percentage of protein and at what stage does it yield the most dry matter and total protein?
2. What are the merits of Kentucky bluegrass?
3. Why is timothy the great hay grass of this country and what are its bad points? When should it be cut for hay?
4. Discuss the value of red top, orchard grass, brome grass, and the millets.
5. What is the importance of the cereal grains for forage?
6. Name and discuss the value of four grasses adapted to the South.
7. What mixtures are most successful in your own locality for pasture and permanent meadow?
8. Discuss the abuse of pasturage.
9. How may straw be used in stock feeding? Compare the value of the different kinds of straw.
10. Describe the method followed to secure the best hay. How is hay made on a large scale?

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[4] Barnes, Western Grazing Grounds, p. 139.

CHAPTER XIV

LEGUMES FOR FORAGE

The cereal grains, forage from corn and the sorghums, and hay from the smaller grasses are all low in protein compared with carbohydrates and fat. Therefore, when only these crops are raised, the stockman must purchase large amounts of expensive protein-rich concentrates to provide balanced rations for his stock. Fortunately, the great group of legumes furnish bounteous crops of protein-rich, palatable roughage that greatly reduces the need for purchased concentrates. Indeed, for many classes of animals merely legume hay and the farm-grown grains furnish a most satisfactory and well-balanced ration. The high feeding value of the legumes is due not only to their richness in protein, but also to the abundance of lime they contain. Tho this is required in large amount by growing animals and those which are pregnant or giving milk, it is low in the cereal grains and present in only fair amount in forage from corn and the other grasses. Equally important is the fact that the legumes are able to increase the supply in the soil of nitrogen, the most expensive plant food. Their abundant and systematic growth on every farm is thus necessary for the economical maintenance of soil fertility. Due to these excellencies, the legumes are the best crop allies of the stockman in reducing his bills both for purchased feed and for commercial fertilizers.

In considering the legumes it must be kept in mind that they flourish and build up the nitrogen content of the soil only when the proper nodule-forming bacteria are present. Where these nitrogen-fixing bacteria are lacking in the soil, it is necessary that it be inoculated by some means.

I. Alfalfa

Importance of alfalfa.—Tho alfalfa is especially adapted to the semi-arid plains and the irrigated districts of the West, it can be profitably grown in most districts of the United States where the soil is deep, well-drained, and rich in lime. The acreage of alfalfa in this country doubled from 1899 to 1909, and increased over eight-fold in the states east of the Mississippi. The reason for this surprising advance is revealed in the following table, which shows the average yield per acre in 1909 thruout the United States of four of our most important crops.

Average returns per acre from alfalfa and other crops

	Yield per acre Lbs.	Digestible crude protein Lbs.	Total digestible nutrients. Lbs.	Net energy Therms
Alfalfa hay	5,040	534	2,601	1,734
Clover hay	2,580	196	1,313	896
Timothy hay	2,440	73	1,183	819
Corn (ears and stover).	3,440	146	2,256	1,762

This average for the United States shows that alfalfa produced by far the largest yield per acre, with over 2.7 times as much digestible crude protein as clover and nearly four times as much as corn. It excelled even corn, the king of forage crops, in yield of total digestible nutrients, tho, due to the high net energy value of the corn grain, the corn crop surpassed alfalfa in yield of net energy.

Much larger yields of alfalfa than the average shown in the table are easily secured under favorable conditions, even in the eastern states. When amply watered by irrigation, alfalfa furnishes 2 to 5 cuttings a season, yielding as high as 5 tons of nutritious hay per acre. In the hot irrigated districts of the Southwest 9 or even more cuttings have been secured in a season. When high temperature is combined with a humid climate, alfalfa generally fails unless the soil is unusually favorable. Where both soil and climate are suitable, this long-time perennial returns good crops for many years without reseeding.

Alfalfa for hay.—Tho alfalfa hay is richer in protein than red clover hay, it contains slightly less carbohydrates and is lower in fat. Alfalfa hay is thus somewhat more valuable than clover hay in balancing rations low in protein, but when fed with concentrates containing ample protein is not superior to clover. The chief superiority over clover lies not in a higher feeding value per ton but in the fact that where alfalfa thrives it yields more tons of hay per acre.

Alfalfa should be cut for hay as soon as new shoots are well started at the crown of the plant. Cutting later than this reduces the yield of the next crop, for many of the longer shoots will be clipped by the mower. By harvesting the crop at this early stage the maximum yield for the whole season is obtained, and the hay is more leafy and palatable. It also contains more protein and is more digestible than if cut later, when it contains more fiber. Early-cut hay is preferable for all farm animals except the horse, for which late-cut is better since, tho less nutritious, it is less washy. In certain sections of the West the first cutting often contains much wild foxtail, or squirrel-tail grass, which has coarse beards that are injurious to stock if the hay is cut at the usual stage. In such cases the alfalfa may be cut earlier, when the young foxtail will make good hay, or the crop may be ensiled, which will soften the beards.

Feeding alfalfa hay.—Since it is rich both in protein and in mineral matter, especially lime, which is needed in large amount in milk production, alfalfa hay is a most excellent feed for dairy cows. Moreover, it is highly palatable and has a beneficial laxative effect. The statement sometimes made that alfalfa hay is equal to wheat bran for dairy cows is not true, however. It supplies only about nine-tenths as much digestible crude protein as bran, contains nearly 3 times as much fiber, and furnishes only 70 per ct. as much net energy. Altho much less concentrates are needed when alfalfa hay is fed than when a roughage like timothy hay is used, all the concentrates in the ration cannot be replaced, even by this most valuable roughage, without reducing the milk yield of the cows.

Fig. 50.—Cutting Alfalfa in a Western Irrigated District

Wherever it thrives, the acreage of alfalfa is rapidly increasing, due to the large yield of excellent hay it produces. (From U. S. Reclamation Service.)

The fattening of cattle and sheep in the western states has been revolutionized by the use of alfalfa hay, due to the large and economical gains secured when this protein-rich roughage is fed with the carbonaceous grains and perhaps silage or wet beet pulp. Breeding cattle and young stock wintered on alfalfa hay, preferably with silage in addition, will more than maintain their weight. For breeding ewes, alfalfa hay is equally satisfactory. Owing to the fondness of horses for this roughage, the allowance should be restricted, lest they overeat. Fed in proper amount, alfalfa hay has given satisfaction as the only roughage, even for horses at rapid work. Alfalfa hay can be largely used in maintaining breeding swine in winter, and even for fattening pigs a limited amount may aid in producing cheap gains.

Pasturing alfalfa.—Alfalfa is not primarily a pasture plant, for, particularly in humid regions, grazing is apt to injure the stand. Moreover, cattle, and especially sheep, run risk from bloat when on alfalfa pasture. Nevertheless, it furnishes such nutritious feed that it is grazed on many farms even in the humid eastern states. To avoid serious injury to the stand, the fields should not be pastured until the stand has become well established, and animals should be kept off when the ground is soft, muddy, or frozen. Heavy stocking of the pasture is decidedly injurious, especially with horses and sheep, which gnaw the plants to the ground. Except where the winters are mild, alfalfa should be allowed to grow to a height of 6 to 12 inches in the fall for winter protection.

Alfalfa pasture is excellent for horses and pigs, which are not subject to bloat. For colts and young horses the succulent alfalfa, rich in protein and mineral matter, is especially helpful. On thousands of farms it is the foundation of cheap pork production. The danger to cattle and sheep from bloat varies greatly with climate and other factors. Tho there is always some risk, in such districts as the hot irrigated sections of the Southwest but little loss is experienced. Where cattle or sheep are grazed on alfalfa the following precautions should be taken:[1]

> For permanent pasture sow with alfalfa, bluegrass, brome grass or some other grass adapted to your particular conditions. Use upland in preference to lowland for pasture, and have a constant supply of water for the stock. Frosted alfalfa is especially dangerous, but in the late fall after the crop has dried it may be grazed again. Before turning animals on alfalfa for the first time, allow them to fill up on grass pasture, with grain in addition if they have been accustomed to it. Then in the middle of the forenoon, when they do not care to graze longer, turn them on the alfalfa. Tho some advise allowing the stock to graze only a few minutes the first day and gradually increasing the length of time on the following days, it is probably safer to keep them on the pasture continuously, for they will then never consume undue amounts at one time. Watch the stock closely for the first few days and remove permanently those animals which show symptoms of bloat, for individuals differ in their susceptibility to the trouble. A method used in the San Joaquin valley, California, when starting cattle on alfalfa pasture is to cut part of a field and turn the cattle on this portion after the alfalfa is half dry. Then after they are well filled they are allowed to eat whatever of the green crop they wish.

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[1] Partly adapted from Coburn, The Book of Alfalfa, pp. 109–119; and Wing, Alfalfa Farming in America, pp. 338–344.

Alfalfa for soilage.—Alfalfa is one of the most valuable of all soiling crops, owing to the large yields and to the fact that under proper management it will furnish rich succulence thruout the entire summer. Much more forage, even twice as much in some cases, is secured from a given acreage as soilage than when it is pastured. In certain hot irrigated sections of the West where no grasses make satisfactory summer pasture dairy cows are often maintained chiefly on alfalfa soilage during much of the year. Whether it is profitable to feed alfalfa as soilage rather than to pasture it will depend on the relative cost of land and labor.

Alfalfa silage.—In some instances alfalfa is ensiled with success, tho often a poor, vile-smelling silage is produced. The difficulty seems due to the high protein content of the crop compared with the small amount of sugars, from which the acids necessary to preserve the silage are formed. Owing to the palatability of good alfalfa hay, there is little reason for ensiling the crop, except when it cannot be cured in a satisfactory manner. Eckles has recently found at the Missouri Station that alfalfa made satisfactory silage when allowed to dry out partially before ensiling by allowing it to lie in the swath for a few hours. Better silage is also made when alfalfa is ensiled along with crops rich in sugars, such as rye or wheat cut when just past the milk stage, or green corn or sorghum.

Alfalfa meal and feed.—The manufacture of alfalfa meal (ground alfalfa hay) and various feeds containing more or less of this material has increased rapidly of late. For animals having good teeth and time to chew their food, grinding hay does not increase its digestibility or feeding value. For such animals the only advantages of the meal are that it may be easier to transport and there is somewhat less waste in feeding it. The bulky meal is also helpful in diluting heavy concentrates, which might cause digestive troubles if carelessly fed. Hay can, however, be readily chopped sufficiently fine for this purpose on the farm by merely running it thru a silage cutter. Unless good alfalfa meal sells at an appreciably lower price than wheat bran, its purchase cannot be recommended, for its feeding value is lower. Ordinarily, the stockman can produce roughage cheaper on his farm than he can buy it in feed sacks. Often one cannot tell by its appearance whether the meal has been made from nutritious, early-cut hay or from over-ripe, stemmy material. It should therefore be bought on a guarantee of composition, and the fiber content should not be over about 30 per ct.

Molasses, either beet or cane, is frequently mixed with alfalfa meal, the product being sold as "alfalmo" or under other names. The mixture is well-liked by stock, but its economy as a feed must be determined by comparing the composition and price with those of other feeds. Many mixed feeds, discussed in Chapter XI, contain more or less alfalfa meal.

II. RED CLOVER

Medium red clover.—This clover, commonly known simply as red clover, is the most important legume in the humid sections of the northern two-thirds of the United States, where, grown in rotation with corn and the cereals, it so helpfully serves for hay and pasture production and for the maintenance of soil fertility. Clover is chiefly seeded in combination with timothy, 19,542,000 acres of mixed clover and timothy being grown for hay in the United States in 1909, compared with only 2,443,000 acres of clover alone. Red clover does best on well-drained soils rich in lime, not thriving on a water-logged or acid soil. But few plants live over 3 years, and the crop is usually treated as a biennial.

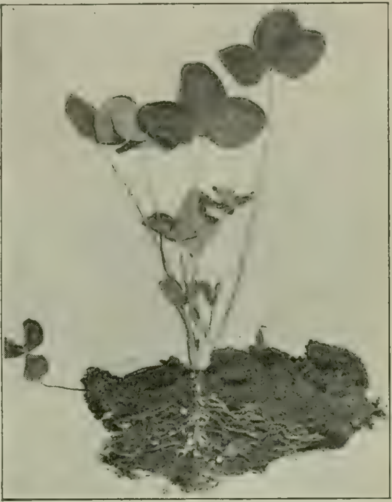

FIG. 51.—A Young Red Clover Plant, Showing the Tubercles on the Roots. (From U. S. Department of Agriculture.)

Red clover generally yields a heavy first crop of hay, with a lighter second cutting, which is often allowed to mature for seed. In the southern states, where it does not thrive during the heat of summer, red clover is sometimes grown as a winter annual, the first crop being cut in the spring and the second in early summer. The average yield of clover hay per acre, according to the census of 1910, was 1.29 tons, but under favorable conditions much higher returns are secured, the yield in 2 cuttings ranging from 2 to 4 tons or even more per acre. Where it flourishes, alfalfa out-yields red clover. However, red clover is better adapted for short-time rotations with other crops like corn and the cereals than the longer-lived alfalfa, which is often difficult to establish and is therefore grown in the same field for many years, if possible. In their eagerness to grow alfalfa many eastern farmers are unfortunately neglecting the clovers, which are vitally helpful in keeping up the fertility of the whole farm thru short-time rotations. In many cases the growing of red or mammoth clover has been abandoned on account of failure to secure stands. Such "clover sickness" of the soil may be due to certain diseases, but in most cases it means that lime, phosphate, and possibly potash are needed. Farmers who willingly prepare fields thoroly for alfalfa often fail to make reasonable efforts to get good stands of clover.

Red clover for hay.—Clover yields the largest amount of hay per acre, and also more crude protein, nitrogen-free extract, and fat when cut at full bloom. After this period only the fiber increases, the other nutrients growing less, due to the withering and dropping of the lower leaves and the leaching of the plants by rains. This shrinkage of nutrients as clover matures is similar to that in the smaller grasses and opposite to what occurs in the corn crop. While full bloom is theoretically the best time to cut clover for hay, practical experience shows that it is best to wait until about one-third of the blossom heads have turned brown. This is because at any earlier date the plant is so soft and sappy that it is difficult to cure it into good hay. Delaying until all the heads are dead makes haying still easier, but means a poor, woody, unpalatable product.

Clover for hay.—Well-cured clover hay, bright and with leaves intact, is an excellent roughage for all farm stock. Tho dusty clover hay is to be avoided for feeding horses, that of good quality is successfully and economically used with both farm and city horses. Mixed clover and timothy hay is preferred by many to clear clover hay for horse feeding, since it usually is freer from dust.

No investigations of the experiment stations in animal husbandry have been more helpful than those showing the great value of the legumes for fattening cattle and sheep. By adding clover hay to the ration, the grain requirement can be materially reduced and the fattening period shortened—both matters of great importance in these days of high-priced concentrates. For the cow, clover hay is unexcelled as a roughage, unless by alfalfa. Where well-cured clover hay furnishes one-half or more of the roughage, the dairyman is able to cut the allowance of concentrates and materially reduce the cost of the ration. This roughage has the same high place for feeding breeding ewes, wintering cattle, and especially for young animals. Early-cut clover hay ranks next to alfalfa for swine, being especially valuable for breeding stock.

Clover for pasture, soilage and silage.—Clover pasture is helpful and important for all farm animals. It about maintains pigs, so that all the grain fed goes to make gain. Pigs on clover are healthy and have good bone and constitution—points of special importance with breeding stock. Tho there is somewhat less danger from bloat with clover than alfalfa, cattle and sheep should not be turned on clover pasture for the first time while hungry or before the dew has risen. Dry forage, such as hay or straw, should also be placed in feed racks in the pasture.

Clover is particularly valuable for soilage, ranking next to alfalfa, and furnishes 3 or 4 cuttings annually if the weather is favorable. In some cases clover has made good silage, but so many failures have occurred that this plant cannot be recommended for such purpose, except where weather conditions prevent its being properly cured into hay. The same precautions should then be taken as with alfalfa for silage.

III. OTHER CLOVERS AND LEGUMINOUS FORAGE PLANTS

Mammoth clover.—This clover grows ranker than medium red clover, has coarser stems, and blooms 2 to 3 weeks later. It usually lives 3 years or more and thrives better on poor or sandy soil than does red clover. As it is coarser, the hay is more difficult to cure and somewhat less palatable. Since it yields but a single cutting during the season, this clover is frequently pastured for several weeks in the early spring. After the stock is removed the plants shoot up and are soon ready for the mower.

Alsike clover.—Alsike clover flourishes on land too acid or too wet for other clovers and is a hardier, longer-lived plant, enduring 4 to 6 years on good soil. Since it yields but one cutting, it is excelled by red clover where the latter thrives. However, as alsike will grow on ''clover-sick'' soil, it is replacing red clover on many fields. It should be seeded with timothy or other grasses to support the weak stems. Alsike hay is fine-stemmed and fully equal to red clover in value.

White clover.—This creeping perennial thrives in almost any soil from Canada nearly to the Gulf of Mexico, if moisture is ample. In the North it is important in mixed pastures, forming a dense mat of herbage thruout the growing season. In the South it nearly disappears in summer, but reappears in the fall furnishing winter pasturage, and thus combines well with Bermuda grass. Owing to its low growth it does not yield hay.

Sweet clover.—White sweet clover is a biennial widely distributed along roadsides and in waste places over southern Canada and a large part of the United States, thriving best on soils rich in lime. It will grow in soil so poorly drained or so worn and low in humus that alfalfa or red clover will not live. Where these more valuable legumes do not thrive, sweet clover, which was once viewed as a weed, is of considerable value. It may be used for pasture, hay, and soilage, and has occasionally been ensiled. At first animals usually refuse sweet clover, for all parts of the plant contain *cumarin*, a bitter compound with a vanilla-like odor. In spring the herbage is less bitter and animals of all classes can generally then be taught to eat it. When the clover is cured a large part of the cumarin is volatilized, the hay thus being less bitter than the green plants.

Sweet clover seed should be thickly sown so that the stems will not grow coarse, and especially in the second year the crop should be cut when the first blossoms appear, or even before, since after this stage the plants rapidly grow woody. The first season 1 cutting and the second 2 can be secured in the North, and often 3 in the South. The crop should be cut about 6 inches from the ground, for the new shoots grow out not from the crown, as in alfalfa, but from the stems. Sweet clover makes good hay for horses, cattle, and sheep, and furnishes good pasture for pigs. It should be closely grazed to keep the plants from becoming woody. The yellow-flowered sweet clover is two weeks earlier and smaller in growth than the white variety.

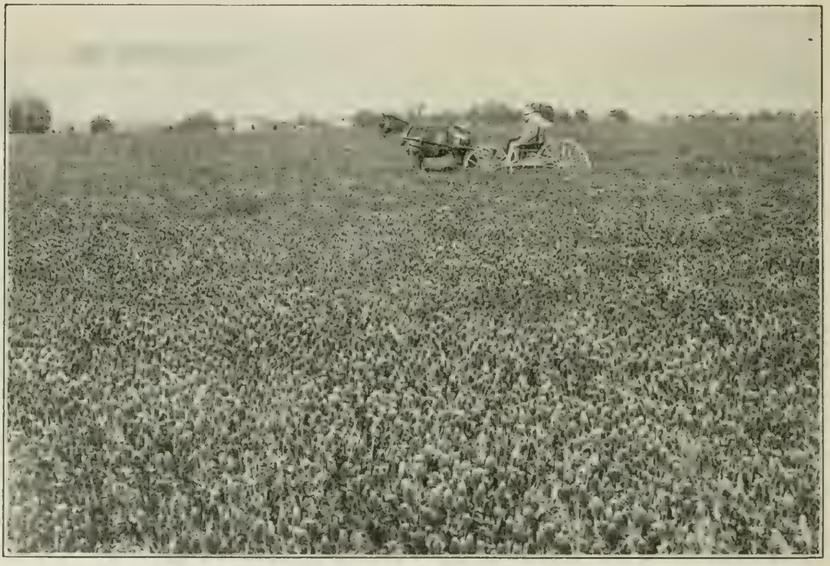

FIG. 52.—A FIELD OF CRIMSON CLOVER IN BLOOM

Crimson clover, grown chiefly as a green manure and a winter cover crop, is also used for pasture and hay. (From *Country Gentleman.*)

Crimson clover.—This annual, adapted to mild climates, is grown chiefly in the Atlantic seaboard states from New Jersey southward. Sown in the late summer or early fall, it blossoms the following spring and dies by early summer. It is grown chiefly as green manure and a winter cover crop, but is also used for pasture and hay, and to some extent for soilage. Crimson clover thrives on both sandy and clay land, if well drained, and has the advantage that the crop may be harvested or plowed under as manure early enough so that other crops may be raised the same year. When grown for hay it is important that crimson clover be cut by the time the flowers at the base of the most advanced heads have faded. After this, the minute barbed hairs of the blossom heads and stems become hard and wiry. If hay from over-ripe clover is fed to horses or mules these hairs sometimes mat together in the digestive tract, forming felt-like masses which plug the intestines, causing death. Cut at the right stage, crimson clover hay is about equal to that from red clover.

Bur clovers.—The *southern bur clover* and the *California bur clover* are winter annuals that furnish valuable pasturage in mild regions. The former, which is the hardier, is found chiefly in the southern states, and the latter in California and Texas. They are admirable supplements to Bermuda pasture, furnishing feed when that grass is resting and reseeding unless grazed too closely. Even on land where summer cultivated crops are grown, bur clover, if once sown, volunteers in the fall.

The common field-pea vine.—The common field pea, discussed as a grain crop in Chapter X, is grown in Canada and the northern states to some extent for forage. Peas and oats, if cut early, make nutritious hay well liked by all classes of stock, and also silage of good quality. The combination is frequently sown as a spring soiling crop, especially for dairy cows, or as pasturage, chiefly for swine. In some of the irrigated Rocky Mountain valleys field peas, usually with a small quantity of oats or barley, are sown extensively and grazed when nearly mature by sheep and pigs.

Pea-cannery refuse.—Formerly the bruised pea vines and empty pods from the pea canneries were used only for manure. This rich by-product is now usually preserved in silos or in large stacks, where the decaying exterior preserves the mass within. The silage has a strong odor but is relished by all farm animals, especially dairy cows, fattening cattle, and sheep.

Cowpea.—This hot weather annual is the most important legume in the cotton belt, furnishing grain for humans and animals, tho chiefly grown for forage and green manure. It flourishes on all types of soil and with but little attention, increasing the fertility of the land and furnishing rich hay, pasturage, soilage, and silage. Sown at corn planting or later, early varieties mature the first pods in 70 to 90 days. The crop may be then cut for hay, or the harvesting considerably delayed without loss. Cowpeas yield from 1 to 3 tons of hay per acre which is equal to red clover or alfalfa in value and is an excellent roughage for horses, cattle, and sheep. When cowpea hay is fed to dairy cows or fattening steers the concentrates may be reduced to one-half the amount needed when a carbonaceous roughage, such as corn stover or hay from the grasses, is fed. To support the vines, cowpeas are often grown with corn or sorghum. Frequently, some of the cowpea seed is picked by hand, and the remainder of the crop grazed by cattle, sheep, or pigs. Cowpeas and corn or sorghum also make palatable protein-rich silage. Thru greater use of cowpeas and the other legumes which flourish there the live-stock industry of the South may be enormously increased.

Soybean.—Soybeans, which mature sufficiently for hay wherever corn may be grown for silage, and are not injured by slight frosts, are better adapted to the northern part of the corn belt than cowpeas. Tho more drought-resistant than cowpeas, they will not thrive on such poor land. The plants, which are bushy, should be cut for hay

FIG. 53.—SOYBEANS WHICH YIELDED 2.5 TONS OF HAY PER ACRE

Soybeans are adapted to the same range of climate as corn and, because of their resistance to drought, are especially suited to sandy soils. (From *Breeder's Gazette.*)

when the pods are well formed but before the leaves begin to turn yellow, for soon thereafter the stems become woody and the leaves easily drop off. The crop yields from 1 to 3 tons per acre of hay equal to cowpea or alfalfa hay in feeding value. While soybeans alone make rank smelling silage, 1 ton of soybeans ensiled with 3 to

4 tons of corn or sorghum forage makes a satisfactory product. For this purpose the soybeans and corn or sorghum may be mixed as ensiled, or they may be grown together. In the South soybeans alone or soybeans and corn are often grazed by hogs. For this purpose the beans should be planted in rows to lessen the loss by tramping, and the hogs should not be turned in until the pods are nearly mature. In the northern states the chief value of soybeans is for sandy land or as a catch crop when clover or other crops fail.

Vetch.—Of the vetches, only the *hairy* or *sand vetch*, and the *common vetch* are important in the United States. Both are ordinarily annuals, tho the hairy vetch especially may live more than a year.

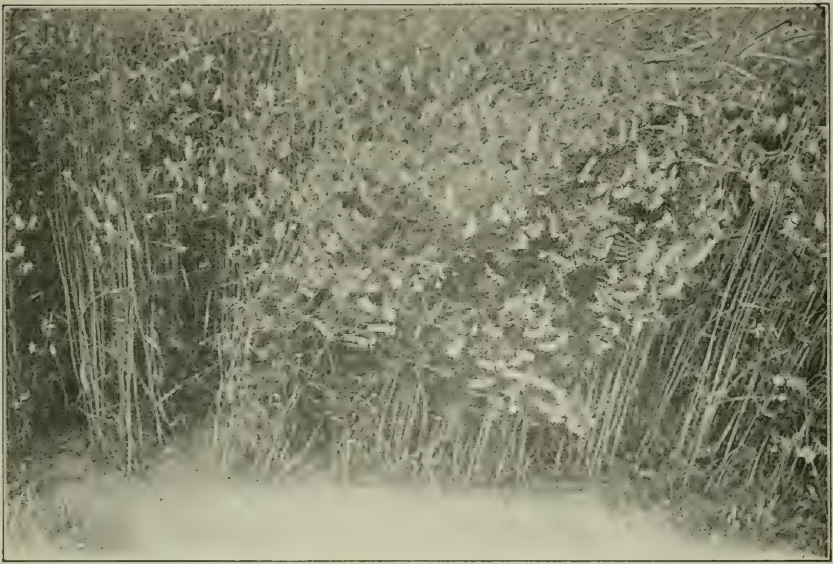

Fig. 54.—Hairy Vetch and Rye in Virginia

As hairy vetch has weak vines which grow from 4 to 10 feet in a tangled mass, it is usually grown with the cereals for hay. (From U. S. Department of Agriculture.)

Being cool-weather plants, in mild climates they are usually sown in the fall. While common vetch is killed by zero temperatures, hairy vetch usually endures the winter in the northern states if well established in the fall. Hairy vetch may be grown in poorer soil than its relative and is markedly drought resistant. It is chiefly grown for hay, being usually sown with the cereals, which support the weak vines that grow from 4 to 10 feet in a tangled mass. Where the winters are mild and the soil rich, common vetch is preferred, as the seed is cheaper and the vines grow less tangled. The vetches yield from 1.5 to 2.5 tons or more of hay per acre and furnish excellent pasturage for cattle, sheep, and swine.

Lespedeza.—*Japan clover,* commonly called *lespedeza* in the South, is a summer annual which has now spread over most of the territory from central New Jersey westward to central Kansas and south to the Gulf. Here, even on the poorest soils, it appears spontaneously in mixed pastures, and unless closely grazed reseeds freely. On the poorer lands of the cotton belt lespedeza is perhaps the most valuable pasture plant, adding nitrogen to the soil, binding it together, preventing washing, and furnishing pasturage well-liked by all stock. This legume has not been known to cause bloat. Only on rich soil does it grow tall enough for hay.

Velvet beans.—The tropical velvet bean flourishes south of a line drawn from Savannah, Georgia, to Austin, Texas. The vines, which run on the ground from 15 to 75 feet, are difficult to cure into hay, and are mostly used for grazing. As high as 30 bushels of shelled beans per acre have been secured. The beans are commonly fed in the pod, 1.5 tons of pod beans being worth as much as 1 ton of cottonseed meal for dairy cows. When fed exclusively, velvet beans produce poor quality pork.

Beggar weed.—This annual legume, which has rather woody stalks 3 to 10 feet high bearing abundant leafage, is used for green forage and hay production in the sub-tropical regions of our country. Cut at the beginning of bloom, when 3 to 4 feet high, it yields from 2.25 to 4 tons of excellent hay per acre.

QUESTIONS

1. What are the advantages of leguminous roughages?
2. Compare alfalfa hay with timothy hay and discuss its importance for stock feeding.
3. How would you use alfalfa for pasture?
4. Discuss the use of alfalfa for soilage; for silage.
5. What is the value of alfalfa meal?
6. Summarize the advantages of red clover in farming and stock feeding.
7. Treat briefly of the value of the other clovers—mammoth, alsike, white, sweet, crimson, and bur.
8. How are field peas used as a forage plant?
9. Discuss the value and uses of cowpeas, soybeans, vetch, lespedeza, and velvet beans.

CHAPTER XV

ROOTS, TUBERS, AND MISCELLANEOUS FORAGES

I. Roots and Tubers

In northern Europe and in eastern Canada root crops are extensively grown for stock, but in this country they have never been widely used. Indeed, in 1909 over 5,000 acres of corn were raised in the United States for each acre of roots grown for feeding. This difference is natural, for northern Europe, with its cool summers, is well suited to growing roots but not corn. In most parts of our country the summers are hot and this imperial grain and forage crop thrives, furnishing in corn silage a palatable succulent feed cheaper than roots. Therefore, growing roots for stock is advisable only in those districts where the summers are too cool for corn, and on farms in the corn belt where too few animals are kept to use silage economically, or where roots serve as a relish for show animals or dairy cows on official test or for swine or poultry.

Use and value of roots.—Since the dry matter of roots is as digestible as that of the grains, roots should not be regarded as roughages, but as watered concentrates. For dairy cows a pound of dry matter in roots is as valuable as a pound of dry matter in corn or barley, and roots can replace half the concentrates ordinarily fed, without reducing the yield of milk or butter. In addition to the nutrients they furnish, roots and other succulent feeds have a beneficial tonic effect upon animals, and are especially helpful in keeping breeding cattle, sheep, and swine in thrifty condition. Many successful stockmen recommend roots highly for animals being fitted for show and for dairy cows crowded to maximum production on official tests.

In this country the daily allowance of roots per 1,000 lbs. live weight is from 25 to 50 lbs. or less, while in Great Britain it is often 100 lbs. or more. Roots are usually chopped or sliced before feeding and often meal is sprinkled over them in the feed box. Considerable straw and other low-grade roughage may be advantageously fed with roots by following the English practice of pulping the roots, spreading them in layers with chaffed straw or hay and shovelling the mass over, and then feeding after several hours, when the roughage is moistened and softened. In the northern states, roots must be stored in winter in well-ventilated pits or cellars; in mild climates they may remain in the fields until fed. In Great Britain sheep are often grazed on root crops, saving the labor of harvesting.

Roots vs. corn silage.—To grow, harvest, and store an acre of roots costs considerably more than to grow an acre of corn and ensile it, because root crops require more thoro preparation of the soil and far more hand labor in cultivation, harvesting, and storage. Moreover, trials at three stations show that corn silage will yield on the average from 68 to 92 per ct. more dry matter per acre than mangels, sugar beets, or rutabagas. Where corn thrives corn silage will furnish dry matter at half the cost of roots or less, and in trials with dairy cows the dry matter of corn silage has proven fully as valuable as that of roots. We should remember that roots are much more watery than silage and that 100 lbs. of roots are therefore worth correspondingly less than 100 lbs. of corn silage. Trials with fattening lambs show 100 lbs. of corn silage is equal to 150 lbs. of roots in feeding value.

The mangel.—The mangel, or mangel wurzel, is the most watery of roots, containing but 9.4 per ct. dry matter. Yet, due to its enormous yield—20 to 30 tons per acre on good soil and sometimes more —it produces a large amount of dry matter per acre. Because it stands well out of the ground, this root is much more easily cultivated and harvested than the sugar beet and it keeps better in winter. Mangels are useful for all farm animals, except possibly horses. However, if fed to rams or wethers for long periods, both mangels and sugar beets produce dangerous calculi, or stones, in the urinary organs. Mangels should not be fed until after storage for a few weeks, as freshly harvested roots may cause scouring. Half-sugar mangels, crosses between sugar beets and mangels, are richer in dry matter than mangels.

Sugar beet.—This root has been so developed for sugar production that some strains now contain 16 per ct. or more of sugar. The yield is smaller than that of mangels, but, due to the higher sugar content, sugar beets generally produce as much dry matter per acre. They demand more labor in cultivating and harvesting than mangels, as they set deep in the ground. They are well-liked by stock and are often fed to dairy cows on test.

Where beets are grown for sugar factories, the cull beets and the tops and leaves should be fed to stock. The tops and leaves may be fed fresh or they may be ensiled, either alone or with an equal weight of dry corn fodder, water being added in the latter case so that the mass will pack well.

Rutabaga.—The rutabaga, or swede, extensively grown in Great

Britain and Canada, ranks next to the mangel in ease of cultivation, and sheep prefer it to all other roots. Like other turnips, rutabagas may taint the milk of cows, and should therefore be fed immediately after milking.

Turnip.—The turnip is more watery than the rutabaga and does not keep so well. Maturing early, turnips are used chiefly for early fall feeding, and often yield large crops, even when sown as a catch crop and without cultivation. Tho used mainly for sheep, they can also be fed to cattle.

FIG. 55.—SUGAR BEETS IN A WESTERN IRRIGATED DISTRICT

While but relatively few acres of sugar beets are grown for stock feeding in this country, the raising of sugar beets for the beet sugar factories is an important industry in certain sections, especially in some of the irrigated districts of the West. (From U. S. Reclamation Service.)

Carrot.—Under favorable conditions stock carrots yield heavily. They are relished by horses, but should be fed sparingly to hard-worked or driving horses. They are also useful for other stock, especially dairy cows.

Parsnip.—Parsnips, the favorite root with dairy farmers on the islands of Jersey and Guernsey, contain about as much dry matter as sugar beets. They are little grown in this country, on account of the low yield and the difficulty of harvesting.

Potato.—In Europe heavy-yielding varieties of potatoes are extensively grown for stock, but in this country potatoes are not usually fed to stock, unless low in price or too small for marketing. They are fed chiefly to pigs, but can also be given in limited amounts to cattle, sheep, and horses as a partial substitute for grain. For pigs they should be steamed or boiled. The heavy feeding of raw potatoes is not advisable as it induces scouring. The bitter tasting water in which potatoes are cooked should be thrown away, likewise all unripe tubers and the sprouts, which may contain considerable *solanin*, a poison. German experience shows that half the dry matter in rations for fattening cattle and sheep, and one-fourth in those for horses, may be furnished in potatoes. Feeding over 35 lbs. per head daily to dairy cows injures the quality of the butter.

FIG. 56.—SWEET POTATOES AFTER THE VINES HAVE NEARLY COVERED THE GROUND

Sweet potatoes are one of the best root crops for pigs for fall and early winter feeding in the South, and may also be fed to cattle or horses. (From U. S. Department of Agriculture.)

Jerusalem artichoke.—The tubers of this hardy perennial, which resemble the potato in composition, are sometimes grown for stock. The tubers live over winter in the ground and enough are usually left to make the next crop. They may be harvested like potatoes, or pigs may be turned in to gather the crop, being fed grain in addition.

Tho the artichoke has been highly praised, nowhere in this country does it seem to be grown continuously—a significant fact.

Sweet potato.—This southern crop, which may be grown as far north as New Jersey and Illinois, serves chiefly for human food, but is also fed to stock, especially pigs, which do their own harvesting. The crop is especially suited to sandy land. Tho the average yield is 90 bushels per acre, some farmers raise 200. Sweet potatoes are one of the best root crops for pigs for fall and early winter grazing, and may also be fed to cattle or substituted for half the corn in rations for work horses. The vines, tho difficult to gather, are often fed in the green state.

Chufa.—The chufa sedge, frequently a weed on southern farms, produces small, chaffy tubers that are relished by pigs, which are turned in to harvest the crop. They are low in digestible protein and should be supplemented by protein-rich feeds. In one trial a good crop of chufas produced 592 lbs. of pork per acre, after allowing for the other feed consumed by the pigs.

Cassava.—The cassava, a bushy plant growing from 4 to 10 feet high, yields fleshy roots, like those of the sweet potato. Tropical varieties carry much prussic acid and must be heated before feeding, but those grown in this country are not poisonous. The culture of cassava in the United States has declined in recent years, due to the fact that sweet potatoes give larger yields at less expense.

II. Miscellaneous Succulent Feeds

Rape.—Dwarf Essex rape, a member of the turnip and cabbage family, now widely grown thruout the United States, stores its nutriment in the numerous leaves and stems. Bird seed rape is worthless for forage. While rape may be used for soiling, it is best to let stock harvest the crop. The plants should never be grazed so closely that only the bare stalks remain, or the yield of new leaves will be reduced.

The seed, which is inexpensive, may be sown from early spring to August in the North and even later in the South, either broadcast or in drills and cultivated. It may also be sown in corn previous to the last cultivation. In 6 to 12 weeks after seeding the crop is large enough for use. As it endures quite severe frosts, rape is excellent for late autumn feed.

Rape ranks high as a pasture crop for sheep and pigs, for which it is chiefly used. To avoid tainting the milk of dairy cows, it should be fed or grazed only directly after milking. Cattle having the run of a rape field in the fall will go into winter quarters in high condition. Access to clover or bluegrass pasture when on rape is advantageous to stock, especially cattle and sheep, as it reduces the danger from bloat. Animals on rape should be freely supplied with salt, as this tends to check any undue laxative effect.

Cabbage.—Cabbage is little grown for stock feeding in this country, because of the labor required in its cultivation. It is sometimes fed to milch cows, and is a favorite with shepherds when preparing stock for exhibition.

Kohlrabi.—Tho yielding less than the rutabaga, kohlrabi, another member of the cabbage family, can be grown wherever the former thrives. Since the thickened, turnip-like stem stands well above ground, it is readily pastured by sheep. Kohlrabi has not been known to taint the milk, when fed to dairy cows.

Kale.—This cabbage-like plant, which does not form heads, is grown extensively in Washington and Oregon, where it is considered the best soiling crop for dairy cows. Yields of 35 to 45 tons and even more are secured on rich soil. In the mild climate of that section kale is fed from October to April, as it endures frost. Unless fed after milking it may taint the milk of cows. Kale is also excellent for sheep and swine.

Pumpkin, squash, and melon.—Pumpkins are often planted in corn fields and the fruits used as relishes for stock. For dairy cows 2.5 tons of pumpkins, including seeds, are equal to 1 ton of corn silage. Tho often cooked for pigs, raw pumpkins give just as good results. The seeds of pumpkins, sometimes removed thru a mistaken idea that they are harmful, are full of nutriment and should not be wasted. With pigs, they act as a vermifuge and put the digestive organs in good condition. As the seeds are rich in protein and oil, eating an excess may cause digestive disturbances. Squashes and melons, especially citrons, are also fed to stock.

Apples and other fruits.—Windfall apples, pears, peaches, plums, oranges, figs, etc., may often be fed advantageously to stock, and with an unprofitable fruit market even sound fruit may be thus utilized. The chief nutrients of fruits are the sugars, and, since they are all low in protein, they should be fed with protein-rich feeds. For dairy cows apples have 40 per ct. of the value of corn silage, while apple pomace is almost equal to it. When fed with shorts and skim milk to pigs, 100 lbs. of apples have equalled from 9 to 15 lbs. of concentrates.[1]

Sagebrush, saltbush, and the greasewoods.—These plants of the desert flourish on the western plains where drought, alkali, and common salt shut out most of the ordinary forage crops. On many ranges they furnish much of the feed consumed by stock. The Australian

[1] Utah Bul. 101.

saltbush, introduced into California and Arizona, will produce 15 to 20 tons of green forage per acre under favorable conditions, or 3 to 5 tons of coarse hay which has about the same digestibility as oat hay.

Cacti.—During periods of drought the cacti, especially prickly pears, are a boon to stockmen of the arid western regions. Because of their peculiar structure and habits, cacti can survive long droughts, tho they make little growth at such times. Prickly pear cacti may be fed where they stand by first singeing off the spines with a gasoline torch, or they may be gathered and run thru machines which chop them in such a manner that the spines are comparatively harmless. Cacti grow but slowly on the range, and can usually be harvested but once in 5 years, even under favorable conditions.

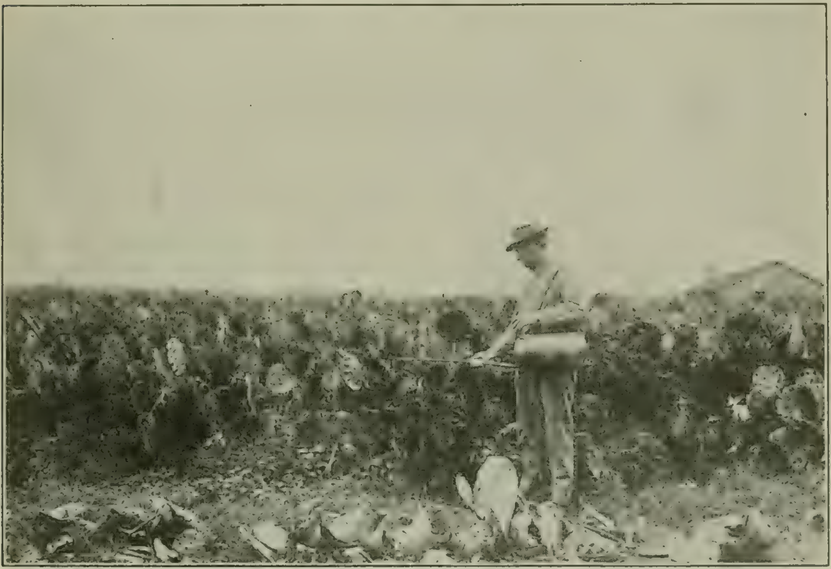

FIG. 57.—SINGEING PRICKLY PEAR WITH A GASOLINE TORCH

After the spines have been singed off cattle can feed on prickly pear without harm. Another method is to cut the cacti and run them thru machines which chop them, rendering the spines comparatively harmless. (From U. S. Department of Agriculture.)

Prickly pear cacti contain about 16.5 per ct. dry matter, being less watery than roots, and cane cacti contain somewhat more dry matter. Since they are low in protein, all the cacti should be fed with a protein-rich concentrate or roughage. Cacti alone do not maintain stock. Tho desert cattle sometimes subsist on them for 3 months of the year, they become very emaciated. Fed in large amounts with no dry feed cacti tend to produce scours.

Spineless cacti, long known, but of late exploited as a novelty, have only limited usefulness for stock feeding, both because they do not survive where the temperature falls below 20° F., and because on the open range cattle readily destroy them. Moreover, in the West, they must be enclosed by rabbit-proof fences.

The chief importance of cacti will undoubtedly be to furnish emergency forage for stock in the semi-arid plains regions. For this purpose plantations of the spiny cacti may be established on the open range, where they will be able to grow and hold their own until serious drought, for cattle will not graze them when other feed is available. All cacti have little value in humid regions.

Sunflowers.—Recently a tall variety of sunflowers, Mammoth Russian, has attracted considerable attention as a silage crop, especially in districts of the West where the season is too short and cool for corn. Sunflower silage resembles in composition silage from rather immature corn but furnishes slightly less digestible nutrients. Large yields have been secured and the silage has been fed with good to fair results to cattle and sheep. Sunflowers have also been used as a soiling crop. Where corn or the sorghums thrive, sunflowers should be raised only in an experimental way until their value for that particular locality has been determined.

III. POISONOUS PLANTS

Only the briefest mention can be made of the leading plants poisonous to stock. One in trouble should send suspected specimens to the experiment station of his state, or to the United States Department of Agriculture.

Plants carrying prussic acid.—Prussic acid, a deadly poison, is found in many plants. The leaves of the wild cherry, especially when wilted, are particularly fatal to cattle. When the sorghums, both sweet and grain varieties, are stunted by drought, enough prussic acid may develop to kill cattle grazing on them. Caution should be used in feeding stunted or second-growth sorghum, kafir, Johnson-grass, etc. Wilted or cured sorghum and sorghum silage are not poisonous.

Ergot.—The seeds of rye and many of the grasses are sometimes attacked by a fungus which produces poisonous black masses known as ergot. Affected animals should have their feed changed to remove the cause, and be warmly housed and liberally fed.

Forage poisoning. During recent years serious losses of stock have occurred from forage poisoning, or "blind staggers," caused by eating moldy feed or drinking water that has passed thru moldy vegetation. Horses and mules succumb most easily but cattle are also affected. The mortality is high in well-developed cases; therefore, animals showing the slightest symptoms should have their feed changed. If moldy feed must be given, it should be fed sparingly and mixed with other feeds of good quality.

Cornstalk disease.—All efforts to determine the cause of a mysterious and fatal ailment, called corn-stalk disease, which attacks cattle turned into stalk fields during fall and winter in the West, have failed. Danger can be avoided by cutting and shocking the corn and feeding the fodder or the stover after husking.

Corn smut.—Since cows have been fed as much as 10 lbs. of corn smut daily for considerable periods without harm, it is reasonable to hold that it is not generally dangerous to cattle.

Loco poisoning.—In Colorado alone a million dollars has been lost annually thru "loco" poisoning, brought on by eating various plants, mostly legumes, which in certain regions may contain barium salts. The trouble is most prevalent in the spring, when the emaciated range animals are forced because of scanty forage to eat plants they would ordinarily reject.

Castor beans.—Castor beans and castor pomace contain a deadly poison, which may be destroyed by exposing the castor oil cake or the seeds to the air for 5 to 6 days, or by cooking them for 2 hours.

Miscellaneous poisonous plants.—The common horsetail, water hemlock, poison hemlock, death camas, several species of larkspur, cockle bur, woody aster, and many other plants are more or less poisonous to stock. However, animals seldom eat poisonous plants unless forced to do so by hunger. When grazing is short, stock should be kept away from areas definitely known to be infested with such plants.

QUESTIONS

1. Discuss the uses of roots for stock feeding.
2. Compare the value and economy of roots and corn silage.
3. Name the five most important root crops for the North and discuss their value.
4. Of what value are potatoes for stock?
5. Name three root crops grown only in the South and state their merits.
6. State the value and uses of rape for stock.
7. Discuss the value of three other members of the cabbage family.
8. What are the uses of sagebrush, saltbush, the greasewoods, and the cacti?
9. Name some of the plants poisonous to stock.

CHAPTER XVI

SILAGE—SOILAGE

I. Silage and the Silo

The preservation of green forage by placing it in pits or heaps and covering with earth has long been practiced in Europe. However, silos—special structures built mainly above ground to contain such material—have been in use only during the past 40 years. From 1879, when the first silo was built in this country, the use of silage has increased rapidly, until now it is a factor of vast importance in American agriculture.

How ensiling preserves forage.—When green forage is packed firmly in a chamber with air-tight walls, such as a silo, fermentations take place, caused both by the enzymes contained in the plant cells and by bacteria and yeasts carried into the silo on the forage. During these fermentations much of the sugar in the forage is broken down into organic acids, chiefly lactic acid (the acid in sour milk) and acetic acid (the acid in vinegar). In these changes oxygen is taken up and carbon dioxid (carbonic acid gas) given off. At first the oxygen in the air which has been entrapped in the ensiled mass is used up, but if the forage has been well packed, this is soon exhausted. The enzymes and bacteria then obtain the oxygen for these decompositions from the oxygen-containing compounds in the forage—chiefly the sugars. When the sugar in the forage has been changed into acids the fermentation is checked, for the other carbohydrates are attacked to only a small extent. It is due to this that corn or sorghum makes less acid silage when well matured than if ensiled when the plants contain more sugar. Even tho much sugar is present, the fermentation finally comes to an end, for sufficient acid is produced to prevent both the further growth of the bacteria and yeasts and the action of the plant enzymes. During the fermentation the temperature rises somewhat, but rarely reaches 100° F. if the mass has been well tramped to exhaust the air.

The acid in silage prevents the growth of undesirable putrefying bacteria, such as cause the decaying of meat. The foul-smelling silage often obtained from alfalfa, clover, and other legumes is largely due to the fact that not enough sugar is present in such plants to form sufficient acid to check the growth of these putrefying bacteria.

After a few days the silage-making processes cease, and no appreciable changes will take place so long as the air is excluded. Instances are on record where silage made 12 to 14 years before has been found to be of excellent quality. Tho the conversion of sugar into acids is the chief change in good silage, a considerable part of the protein is also broken down into amino acids. Since this splitting of the protein into simpler compounds is similar to digestion in the animal, it probably does not lessen the nutritive value.

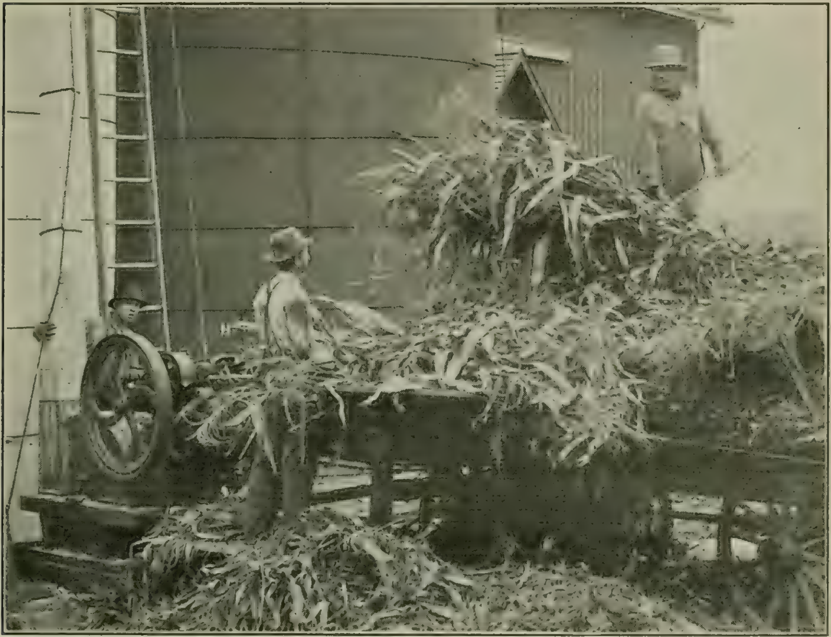

FIG. 58.—SILOS HAVE REVOLUTIONIZED STOCK FEEDING IN MANY DISTRICTS

The silo provides high-quality succulent feed for any season of the year, with a low expense for labor and a minimum wastage of nutrients.

Advantages of silage.—The widespread use of the silo for the preservation of forage is easily explained when we consider the advantages this system offers, the more important of which are:

1. At a low expense silage furnishes high-quality succulent feed for any desired season of the year. The cost of silage per ton will vary widely, depending on the price of labor, the yield of forage per acre, and the rent of the land. However, when average yields are secured the cost of corn silage should not be over $3.50 to $4.00 per

ton, including land rental, cost of manure or fertilizers, seed, labor and other expenses in growing and harvesting the crop, as well as interest and depreciation on machinery. For winter feeding, silage is far cheaper than roots and as efficient, except possibly in the case of animals being fitted for shows and milch cows on forced test. In summer silage furnishes succulent feed with less bother and expense than do soiling crops.

2. When crops are properly ensiled, less of the nutrients are wasted thru the fermentations which take place than are lost when the forage is cured as hay or dry fodder.

3. Silage, even from plants with coarse stalks, such as corn and the sorghums, is eaten practically without waste. On the other hand, from 20 to 35 per ct. of dry corn fodder, even if of good quality, is usually wasted. The use of silage thus permits the keeping of more stock on a given area of land.

4. Crops may be ensiled when the weather is unfavorable for curing them into dry fodder. In some sections of the South the corn crop can not be preserved satisfactorily as grain and stover on account of the dampness and also because rodents and weevils ruin the stored grain. Ensiling the crop overcomes both difficulties.

5. Weedy crops, which make poor hay, may make silage of good quality, the ensiling process killing practically all weed seeds.

6. The product from a given area can be stored in less space as silage than as dry forage. A cubic foot of hay in the mow, weighing about 5 lbs., contains approximately 4.3 lbs. of dry matter. An average cubic foot of corn silage from a 30-foot silo, weighing about 39.6 lbs., will contain 10.4 lbs. dry matter, or nearly 2.5 times as much.

7. Ensiling the corn crop clears the land early so it may be prepared for another crop.

Crops for the silo.—The suitability of the leading crops for silage has been discussed in the preceding chapters. Indian corn is the best silage plant, sorghos and the grain sorghums ranking next in value and importance. Green cereals are fairly satisfactory for silage, if ensiled before the stems become woody, and if the cut forage is well tramped to force the air out of the hollow stems.

The legumes have proved disappointing for silage. Better results have been secured with alfalfa and clover when they are ensiled with other plants which carry more sugar, such as green rye, wheat, corn, or sorghum. Whenever these legumes can be cured into satisfactory hay, there is little need of ensiling them, for more reliable silage crops may usually be grown. When ensiled with corn or the sorghums, cowpeas and soybeans produce silage of high quality, rich in protein. The refuse of pea canneries makes a silage much relished by stock.

Such substances as beet pulp, beet tops, apple pomace, the waste from sweet corn canneries, and sorghum bagasse may be successfully preserved in silos, or placed in heaps and covered with earth, or even massed in large heaps without covering, in which case the outside portion on decaying forms a preserving crust. Weeds and other waste vegetation may sometimes be advantageously ensiled. Cabbage, rape, and turnips make unsatisfactory silage, ill-smelling and watery.

Silage on the stock farm.—Over a large part of the United States the use of silage is a most important means of lowering the cost of producing milk and meat. Apart from the nutrients it contains, this succulent feed aids in keeping stock in thrifty condition so that they will make the most from their feed. Since it furnishes at any time of the year a uniform supply of succulent feed nearly equal in palatability and nutritive effect to the pasturage of early summer, silage is unexcelled for dairy cows, beef cattle, and sheep. With an abundance of silage and legume hay the amount of concentrates which must be purchased or grown may be greatly reduced. Silage is especially valuable for breeding stock and young animals, keeping them in better condition than if wintered on dry forage alone. On too many farms stock cattle barely hold their own during winter. This means that for half of each year all the feed consumed goes for body maintenance, returning nothing to the owner, and serving only to carry the animals over to pasture time, when they once more may gain in weight and really increase in value. By the use of corn silage, combined with other cheap roughages, young cattle may gain steadily all winter at small cost, and by spring they will be in condition to make the largest possible gains from pasture. Silage is a valuable succulence for sheep, but must be fed in moderation to ewes before lambing or weak, flabby lambs may result. Good silage may also be used in a limited way with idle horses and those not hard worked in winter, especially brood mares and colts.

Spoiled, moldy silage should always be discarded, and special care taken to feed no such material to sheep or horses, which are much more easily affected by it than cattle. Silage which is very sour is apt to cause digestive disturbances with sheep. For all animals only as much silage should be supplied as will be cleaned up at each feeding. Care should be taken to remove any waste, for it spoils in a short time on exposure to the air. Frozen silage must be thawed before feeding.

The amount of silage commonly fed per head daily to the various classes of stock is about as follows:

Dairy cows, 30 to 50 lbs. for those in milk, with somewhat less for dry cows; dairy heifers, 12 to 20 lbs.; beef breeding cows, 30 to 50 lbs.; fattening 2-year-old steers, 25 to 30 lbs. at the beginning of the fattening period, the allowance decreasing as they fatten until only 10 to 15 lbs. is fed; brood mares and idle horses, 15 to 30 lbs.; breeding ewes, 2 lbs. (sometimes as much as 3 to 4 lbs. is safely fed); fattening lambs, 1.5 to 3 lbs.

Summer silage.—Many farmers who fully appreciate the value of silage for winter feeding do not realize its value for supplementing dried-up pastures in the summer, or as a partial substitute for pasturage on high-priced land where all the stock possible must be kept per acre. In a 3-year comparison of soilage crops and corn silage as summer supplements to pasture for dairy cows, at the Wisconsin Station,[1] silage proved fully as efficient in producing milk and butter fat as soilage, and was far cheaper and more convenient. To provide a succession of green feed by means of soiling crops, it is necessary to fit and plant comparatively small areas to various crops at different times. As the cut soilage will quickly heat and become unpalatable in warm weather if placed in piles, a supply must be harvested each day, or at least every two or three days. Harvesting in small quantities and in all sorts of weather is inconvenient and expensive, and the work must be done at the busiest season of the year. On the other hand, when corn or the sorghums are grown for silage the large fields are fitted, planted, cultivated, and harvested with labor saving machinery at minimum expense, and feeding the silage takes but a few minutes daily.

Corn and sorghum return greater yields of nutrients than many of the crops it is necessary to include in a soiling system. Silage furnishes feed of uniformly high quality thruout the season, a goal which is difficult to reach by soiling, for one crop is often exhausted or too mature before the next is in prime condition for feeding. The years when drought is severe and pastures unusually short are the very times when soiling crops will be scant or may even fail. By means of the silo, the crop may be carried over from one year to the next, thus providing insurance against drought. In summer feeding, at least two inches of silage and preferably more should be removed from the surface each day, or the exposed material will decay.

Filling the silo.—Especially with such coarse material as corn or sorghum forage, silage keeps much better when cut into short lengths and is therefore usually run thru a silage cutter. The cut material is also easier to remove from the silo. When filling the silo the inpouring material should be thoroly mixed and evenly spread, so it will settle uniformly. The material should be especially well tramped near the wall and kept higher than at the center, as the friction at the wall retards the settling. If the forage is too dry to pack well, water should be added to the mass in the silo or to the cut forage as it passes thru the blower. The forage will settle considerably after the silo is filled, and more may then be put in, any spoiled surface material being first removed. If feeding is not to begin immediately, the surface should be wet down thoroly and tramped well several times the first week, when the rotting forage will form a layer on top that protects the rest. To lessen the waste, it is well to remove the ears from the last few loads of forage and cover the top with cheap refuse such as straw or weeds, wet with water. When feeding begins, all spoiled silage should be discarded.

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[1] Woll, Humphrey, and Oosterhuis, Wis. Bul. 235.

On going into the silo after an intermission in filling, one should always beware of the danger from carbon dioxid. This may accumulate in sufficient quantities to prove fatal. If a lighted lantern or candle lowered into the silo continues to burn, it is safe, but if the light goes out it means death to one entering. Opening a door low down in the silo or pouring in a lot of fresh cut forage will soon drive out the deadly gas.

Types of silos.—Silos may be constructed of wood, solid concrete, concrete blocks, brick, stone, glazed tile, or sheet steel. In the semiarid regions pit silos, preferably with cement lining and curb, are extensively used, but these are impracticable in humid climates. In the southwestern states silos are sometimes built of adobe, reinforced with wire and plastered with cement. The choice between the various types of construction, all of which make good silos when well-built, will depend upon local conditions. This work presents only the primary principles relating to silo construction, advising those interested to secure from the state experiment stations or the United States Department of Agriculture instructions concerning materials and manner of construction suited to their locality.

Requisites of a good silo.—The satisfactory silo meets the following conditions: 1. *Air-tight walls.* The silo walls must be air-tight and the doors fit snugly, for if air gains entrance the fermentations will continue and molds will grow, spoiling the silage.

2. *Cylindrical shape.* In the early silos, which were rectangular, it was exceedingly difficult to pack the mass in the corners so that it would not spoil. The cylindrical silo has no corners, the sides are strong and unyielding, and it provides the largest possible cubic capacity for a given amount of building material.

3. *Smooth, perpendicular, strong walls.* Unless the walls of the silo are smooth and perpendicular, cavities will form along the walls as the mass settles and the adjacent silage will spoil. The walls must be strong and rigid, for while the silage is settling a great outward pressure is developed.

4. *Depth.* By making the silo deep the great pressure compacts all

but the uppermost layers so that the losses thru fermentation are reduced to a minimum. While over 30 per ct. of the dry matter may be lost in the layer of silage near the surface, the loss in the rest of the silo should be less than 10 per ct.

Capacity of silos.—The first part (A) of the following table[2] shows the estimated capacity of silos for well-matured corn or sorghum silage when the silage has been well-tramped and allowed to settle one day, and the silo then refilled. The second part (B) shows the estimated tonnage when the silage has settled for one month or more. The depth indicated is the actual depth of the silage, not the height of the silo wall. It is therefore necessary to have the silo about 5 feet higher than the depth given to allow for settling. The table shows, for example, that a silo 14 feet in diameter, which contains 20 feet of silage one month after settling, will hold about 58 tons of corn silage.

Approximate capacity of cylindrical silos in tons of corn silage

*A. Capacity when filling is completed.**

Inside diameter in feet.	Depth of silage in feet											
	18	20	22	24	26	28	30	32	34	36	38	40
10	20	23	26	30	33	37	41	..	..	..	..	..
12	28	33	38	42	48	53	58	64	70	..	..	..
14	38	45	51	58	65	72	80	87	95	103	111	120
16	50	58	67	76	85	94	104	114	124	135	145	156
18	64	74	84	96	107	119	132	144	157	171	184	198
20	78	91	104	118	132	147	162	178	194	211	227	244
22	95	110	126	143	160	178	196	215	235	255	275	296

*B. Capacity after silage has settled one month or more.***

	Depth of silage in feet											
	8	10	12	14	16	18	20	22	24	26	28	30
10	11	14	17	20	23	26	29	33	36	39	43	46
12	16	20	24	29	33	38	42	47	52	56	61	66
14	21	27	33	39	45	51	58	64	70	77	83	90
16	28	35	43	51	59	67	75	84	92	100	109	118
18	35	44	54	64	75	85	95	106	116	127	138	148
20	43	55	67	80	92	105	118	130	144	157	170	184

* A. If corn is unusually dry when ensiled, deduct 10 per ct. from the capacity given. If corn is dry and very little grain is present, deduct 15 per ct. If silo is filled rapidly and no time is allowed for settling deduct 10 per ct.

** B. For corn ensiled when less mature than usual add 10 to 15 per ct. to the capacity given. If corn is unusually rich in grain, add 5 to 10 per ct. If corn is unusually dry when ensiled, deduct 10 to 15 per ct. If very little grain is present, deduct 10 per ct.

Proper size of the silo.—In determining the size of silo to build, the diameter should be gauged by the amount of silage to be fed daily. In the cooler part of the year at least 1.5 inches, and preferably 2 inches, should be removed from the entire surface each day to keep it from spoiling, and in summer somewhat more. Knowing the number of animals to be fed and the amount for each daily, one can readily calculate how much silage will be fed daily. To use two inches daily from the surface, approximately the following amounts must be fed from silos of various diameters: Diameter 10 feet, 510 lbs. silage; 11 ft., 615 lbs.; 12 ft., 735 lbs.; 14 ft., 1,000 lbs.; 16 ft., 1,305 lbs.; 18 ft., 1,655 lbs.; 20 ft., 2,045 lbs.; 22 ft., 2,470 lbs.; 24 ft., 2,940 lbs.; 26 ft., 3,450 lbs. In cold weather and when the silage is well packed, a somewhat smaller amount may be removed daily.

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[2] From Eckles and Reed, Mo. Bul. 164 and Kan. Cir. 89; and Fitch, Nebr. Cir. 1

When the diameter for the desired silo has been determined, the total amount of silage required for any particular feeding period may be computed and from this the right dimensions found by referring to the table in the preceding article

II. Soilage

Soilage means supplying forage fresh from the field to animals in confinement. This system, which had been long practiced in Europe, was brought to attention in this country nearly 100 years ago thru the essays of Josiah Quincy on "The Soiling of Cattle."

Advantages and disadvantages of soilage.—Compared with allowing animals to gather their food by grazing, soiling has the following advantages. (1) A larger yield, even of the grasses, is secured by allowing the plants nearly to mature before harvesting than by pasturing them. (2) With a properly planned succession of soiling crops, an abundance of palatable feed may usually be supplied thruout the season, so that the production of the animals will not decline if pastures become parched in midsummer. (3) None of the forage is wasted thru being tramped down by the animals or fouled with manure. (4) Less fencing is required. (5) In bad weather cattle will be more comfortable when fed soiling crops in the stable than when grazing.

The chief disadvantages of soilage are the greater expenditure for labor, seed, and fertilizer in producing the crops and for labor in cutting and carrying them to the animals In warm weather soilage will ferment and mold in a short time if left in piles. When but few animals are fed, the green forage may be spread thinly on the barn floor, where it will keep, but soilage thus handled dries out and is less palatable. Where a considerable quantity is harvested at one time, much labor may be saved by using the mower and horse rake. During wet spells the palatability of the soilage is reduced, and it is difficult to harvest and cart the food to the animals without injury to the land. On the other hand, pastures also suffer if grazed while wet.

The place of soilage on American farms.—It has been shown previously in this chapter that silage is a more economical means of supplying succulent feed in summer than is soilage. On farms where too few animals are kept to prevent the molding of the surface of the silage as it is fed off in summer, or where a silo is not available, soilage should be provided to prevent the usual midsummer shrinkage in milk flow with cows, and in flesh with beef cattle or sheep. Under this system animals may be housed in darkened stables away from the flies during the heated portion of the day and fed liberally with fresh cut soilage, being turned to pasture at night for exercise and grazing. It is also wise to supply extra green forage in the fall, if the pastures do not furnish plenty of feed.

FIG. 59.—SOILAGE IS USUALLY LESS ECONOMICAL THAN SILAGE

Providing succulent feed in summer by a succession of soiling crops is usually more expensive than the use of silage, chiefly because it requires more labor. (From Wisconsin Station.)

Because of the high price of labor in this country, it is not usually economical, in regions where good summer pastures may be provided, to maintain cattle in summer on soilage or silage with no pasturage. On high-priced land where it is desired to keep as many animals as possible on a given area, such a system may be the most profitable. In Europe, where labor is relatively cheap compared with land, a much wider use can economically be made of soilage than in the United States.

Crops for soilage.—Among the crops well suited for soilage are the various legumes, such as alfalfa, the clovers, field peas, cowpeas, and soybeans; the cereals, as rye, wheat, barley, and oats; the smaller grasses; and especially corn—sweet corn for early feeding and field corn later—and the sorghums. The adaptability of all these for soilage has been discussed in the preceding chapters.

Soiling crops should not be fed until reasonably mature. Green, immature plants are mostly water, and often cattle cannot consume enough of them to secure the needed nourishment. Where quite green crops must be fed, some dry forage should be supplied. Wherever soilage is practiced, a succession of crops must be carefully planned so that a continuous supply of green forage of the proper stage of maturity will be available over the period desired. It is helpful to prepare a soiling chart which shows the area of each crop to be grown, the date of seeding, the period of feeding, and the estimated yield. Any such attempt will be more or less imperfect at first, but may be modified from growing experience and close study to meet the local conditions.

QUESTIONS

1. Describe the changes that take place when green forage is ensiled.
2. Give seven advantages of silage.
3. Summarize the suitability of various crops for silage. What ones are used in your locality?
4. Discuss the importance of silage for feeding the various classes of stock.
5. What are the advantages of summer silage compared with soilage crops?
6. Mention the points to be observed in filling the silo.
7. What are the requisites of a good silo?
8. A farmer wishes to provide corn silage for a herd of 15 Holstein cows, 8 yearling heifers, 2 idle horses, and 30 breeding ewes during a winter feeding period of 6 months. What size of silo would you recommend?
9. Define soilage and state its advantages and disadvantages.

CHAPTER XVII

MANURIAL VALUE OF FEEDING STUFFS

Unless the plant food removed from the soil by the growth of crops is returned in some form, the land will sooner or later be so reduced in fertility that profitable crops cannot be grown. Already the soil in many once productive areas of this country has been so ''mined'' that good crops are possible only when commercial fertilizers are liberally applied. In 1918 about 3,824,000 tons of commercial fertilizers were sold in the South Atlantic states alone. While the use of commercial fertilizers is wise in some cases, in general farming they should be used to supplement deficiencies only after all the fertility in the feeding stuffs fed to the live stock has been fully utilized.

Farm manure as a fertilizer.—Farm manure, like commercial fertilizers, is valued on the basis of the amount of nitrogen, phosphoric acid, and potash it contains. This is because these are the only plant food constituents removed from the soil by crops which need ordinarily be replaced. The necessary nitrogen may, as we have seen, be indirectly obtained from the air by growing legumes, but in practice much is purchased along with phosphoric acid and potash.

Not only does farm manure supply plant food, but the vegetable or organic matter it contains also helps to increase the productivity of the soil. As this vegetable matter gradually breaks down, the acid products formed help dissolve and make available to plants some of the otherwise insoluble plant food in the soil. Furthermore, the humus formed from the organic matter of manure helps retain moisture, improves the soil texture, renders it more resistant to wind action, and favors chemical and bacterial action which make plant food available. On fields lacking in humus such crops as rye are often grown and turned under as green manure, for the sole purpose of increasing the humus content.

Experiments have shown that the fertilizing constituents in farm manure have as high a value as in such high-grade fertilizers as tankage, bone meal, and muriate of potash. In computing the fertilizing value of feeding stuffs and farm manure, we will therefore use the average market prices of nitrogen, phosphoric acid, and potash in commercial fertilizers when bought in large quantities, i.e., nitrogen 20, phosphoric acid 7, and potash 7 cts. per pound.

Fertilizing constituents recovered in manure.—The animal creates nothing of fertilizing value, for it voids only that which it has eaten or drunk. Part of the nitrogen, phosphoric acid, and potash of the food may be retained in the body during growth or may go into the milk. All the rest is excreted in the urine and feces. The value of the manure therefore depends, first of all, on the kind of feed the animal gets. Only feeds rich in nitrogen, phosphoric acid, and potash make rich manure.

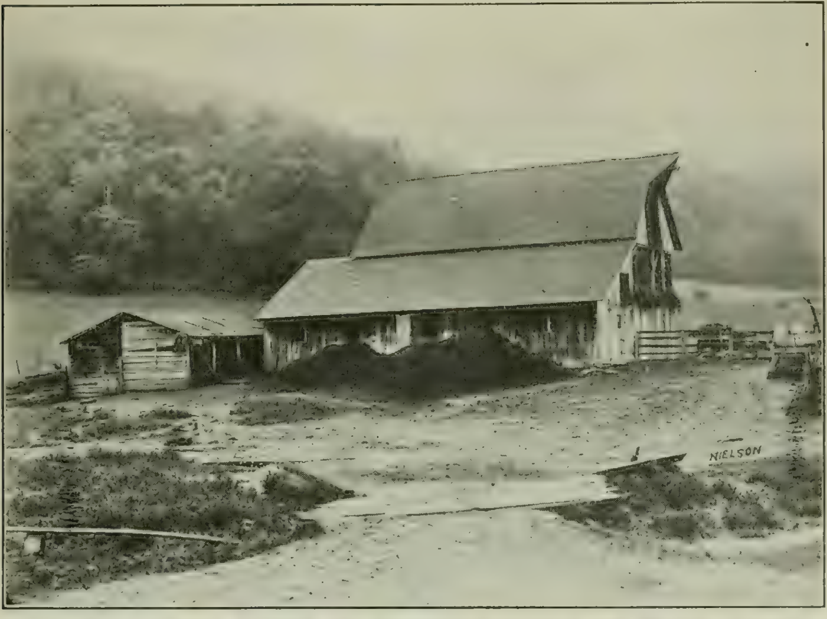

FIG. 60A.—SUCH LOSSES OF FERTILITY OCCUR ON MANY FARMS

When manure is loosely piled under the eaves, heavy losses of fertility occur thru fermentation and leaching. Note that every hard rain will leach fertility from the manure pile to the ditch in the foreground. (From Wisconsin Station.)

The proportion of the total fertilizing constituents supplied in the feed which is recovered in the manure depends on the age and kind of animal. Mature horses at work store no nitrogen, phosphoric acid, or potash, but merely repair their body tissues as they are broken down. Hence, they excrete all the fertilizing constituents contained in their feed. When animals which are nearly mature are fattened, but little nitrogen or mineral matter is stored in the body, over 95 per ct. being put out in the manure. Pigs fattened while still growing and storing nitrogen in their lean meat tissues return in the manure but 85 per ct. of the nitrogen in their feed. Very young animals, growing rapidly in bone, muscle, and body organs, will store in their body most of the fertilizing constituents of their feed. As milk is rich in nitrogen and mineral matter, the cow in milk returns in the manure but about 75 per ct. of the nitrogen and 90 per ct. of the mineral matter of her feed.

Considering the proportion of the various classes and ages of animals on the average farm, probably about 80 per ct. of the nitrogen, phosphoric acid, and potash of the feed is recovered in the feces and urine.

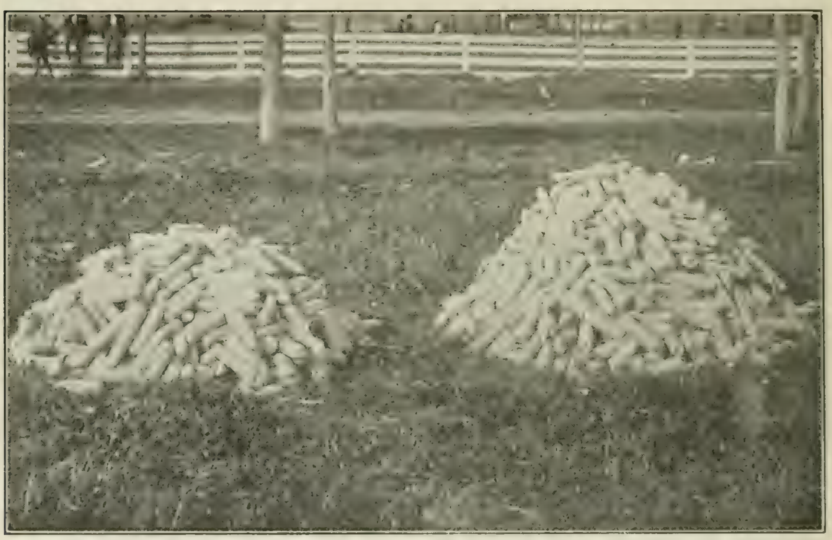

FIG. 60B. RESULT OF ALLOWING MANURE TO WASTE AWAY

When manure is allowed to waste away, as in the preceding illustration, not only is much of the weight of the manure lost, but that which remains contains much less fertility per ton than fresh manure. The pile of corn at the left was grown on a plot fertilized with manure which had been exposed to the weather over winter. The large pile at the right was grown on a plot fertilized with the same amount of fresh manure. (From Wisconsin Station.)

Fertility and manurial value of feeds.—In buying or selling feeds far too few farmers consider their value as fertilizers as well as their feeding value. The amounts of fertilizing constituents in all important feeds are given in Appendix Table III. For comparison, the data for typical feeds and animal products are given in the following table. The fertility value of each has been computed at the rates for nitrogen, phosphoric acid, and potash previously given. The last column gives the average manurial value of the feed. This has been computed on the assumption that, on the average, farm animals return in the manure about 80 per ct. of the total fertilizing constituents in their feed, but that even under good management some losses occur in the nitrogen of the manure which reduce the amount of this constituent to 65 per ct. of the amount in the feed. Obviously, these manurial values hold good only when the manure is so cared for as to prevent as far as possible the losses mentioned later.

Fertilizing constituents in feeding stuffs and animal products

	Fertilizing constituents in 1,000 lbs.			Fertility value per ton	Manurial value per ton
	Nitrogen	Phosphoric acid	Potash		
	Lbs.	Lbs.	Lbs.	Dollars	Dollars
Concentrates					
Dent corn	16.2	6.9	4.0	8.00	5.43
Oats	19.8	8.1	5.6	9.84	6.68
Wheat	19.8	8.6	5.3	9.87	6.71
Wheat bran	25.6	29.5	16.2	16.64	11.78
Cottonseed meal, choice	70.6	26.7	18.1	34.51	23.37
Roughages					
Timothy hay	9.9	3.1	13.6	6.29	4.44
Red clover hay	20.5	3.9	16.3	11.03	7.59
Oat straw	5.8	2.1	15.0	4.71	3.43
Corn silage	3.4	1.6	4.4	2.20	1.55
Animals and products					
Fat ox	23.3	15.5	1.8	11.74	....
Fat pig	17.7	6.5	1.4	8.19	....
Milk	5.8	1.9	1.7	2.82	1.91
Butter	1.2	0.4	0.4	.59	....

The fourth column shows that the nitrogen, phosphoric acid, and potash removed from the soil in a ton of corn grain would cost about $8.00 if bought in commercial fertilizers. On account of its richness in nitrogen, phosphoric acid, and potash, the fertility value of a ton of wheat bran is $16.64, while that of wheat is only $9.87. Because the legumes usually obtain much of their nitrogen from the air, only a part of the fertility in a ton of clover, worth $11.03, may have been taken from the soil. Clover hay is 75 per ct. richer than timothy hay and about 2.3 times as rich as oat straw in fertility.

Of the feeds listed, cottonseed meal has the highest fertility value, $34.51 per ton. This explains why millions of dollars worth of this feed, one of the richest and best for cattle and sheep, are annually applied to southern cotton fields to make another crop of cotton. Where such protein-rich feeds as cottonseed meal are purchased and fed to stock and the proper care is taken of the manure produced, a double return may be realized, the first from the high feeding value of the rich feed, and the second from the manure. With proper care and application, the manure resulting from each ton of cottonseed meal fed would be worth $23.37, the manurial value shown in the table, as surely as would mixed commercial fertilizer costing this amount.

Selling fertility.—The preceding table further shows that those who sell such crops as hay, corn, and wheat, part with more fertility for a given sum than do those who sell animals or their products. The farmer who sells 1,000 lbs. of clover hay, worth $6 to $10, parts with about as much fertility as if he had sold 1,000 lbs. of fat ox or fat pigs, worth $70 to $100, or more. Based on the selling price, milk carries considerable fertility from the farm, and butter practically none. Farm crops may be regarded as raw products, while farm animals, milk, wool, butter, etc., represent manufactured products. A large amount of raw material in the form of grass, hay, corn, etc., is put into animals, and the heavy waste or by-product resulting in the form of manure conserves most of the fertility, when carried back to the fields. The farmer who feeds his crops to live stock is a manufacturer

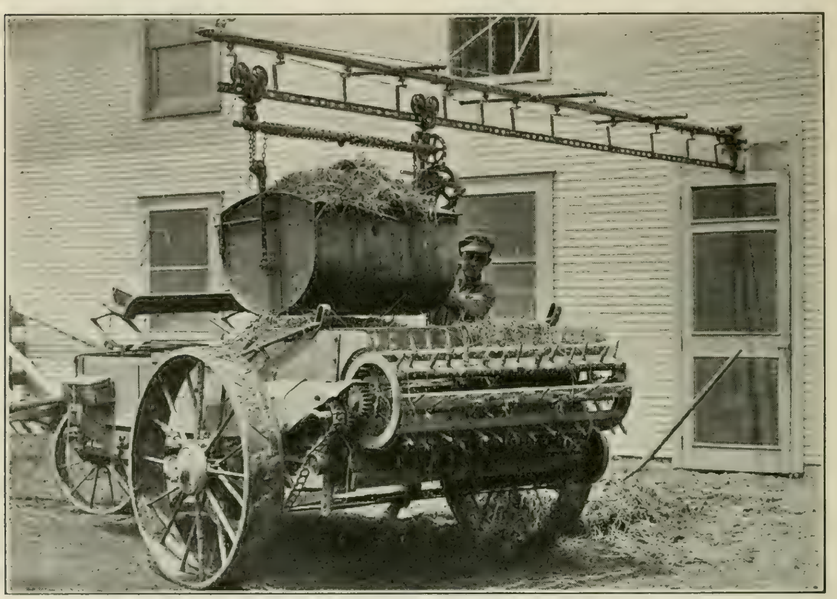

FIG. 61.—SAVING THE FERTILITY IN FEEDING STUFFS

Where possible, the manure should be drawn directly to the fields and spread each day. (From *Breeder's Gazette.*)

as well as a producer, with two possible profits instead of one, while his farm should lose little of its fertility. The farmer who grows and sells grain, hay, and straw is selling a large amount of fertility, the need of which will surely be apparent as time goes on and his fields give smaller and smaller returns. Such a farmer is slowly but surely mining phosphorus and potash from his soil, which can be replaced only by some purchased material.

Virgin soils as a rule contain great quantities of available fertility, and the pioneer farmers in America, drawing upon Nature's store, have given little consideration to how their crops are fed, and have not realized that they are steadily and often wastefully drawing on the fertility which is their principal capital. The western farmer, when marketing corn or wheat, or the southern planter, when selling seed cotton, considers he is selling labor and rent of land. Rarely does he realize that he is also selling fertility, to replace which would cost a considerable part of all the crop brings. Rather than to reckon the value of his crop at the market price, he should recognize that its true value when sold from the farm is really the market price minus the value of the fertility which the crop removes from the soil.

In Great Britain, where many of the farmers are long-period tenants, the manurial value of feeding stuffs is recognized by law. When a tenant vacates his leasehold he is paid for the manurial value of feeds which he has recently purchased and fed on the farm, and, under certain conditions, for the manurial value of grain produced on the farm and fed to stock. Similar provisions should be drafted into farm leases in this country.

Composition and value of fresh manure.—Tho the value of the manure produced by each class of animals varies with the nature of the feed supplied, it is important to study the average composition of manure for each class, as given in the following table.[2]

Composition of one ton of average manure from farm animals

	Water Per ct.	Nitrogen Lbs.	Phosphoric acid Lbs.	Potash Lbs.	Value Dols.
Horse manure	78	14	5	11	3.92
Cow manure	86	12	3	9	3.24
Sheep manure	68	19	7	20	5.69
Pig manure	87	10	7	8	3.05

Horse or sheep manure contains less water than that of cows or pigs, and these are known as "hot manures" because their low water content permits rapid fermentation, or heating, when stored. On the other hand, the voidings of the cow and pig form "cold manures," the high water content checking fermentation. Sheep manure has the highest value per ton, based on the fertility it furnishes, and pig manure the lowest. Mixed farm manure contains about 10 lbs. of nitrogen, 5 lbs. of phosphoric acid, and 10 lbs. of potash per ton.

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[2] Adapted from Van Slyke, Fertilizers and Crops, p. 291.

The total value of the manure produced annually by the various farm animals per 1,000 lbs. live weight is about as follows: horse, $30.70; cow, $36.51; sheep, $30.94; and pig, $40.24.

Losses in farm manures.—While manure is one of the most valuable products of the farm, many farmers who freely purchase commercial fertilizers allow much of the value of the manure produced by their live stock to be washed away in streams or otherwise needlessly lost. It is most important to realize that manure is a highly perishable product, and that unless proper care is taken of it over half its value may be lost. Plant food may be wasted thru: (1) Loss of urine, (2) loss by leaching, (3) loss of nitrogen by fermentation. Tho all the phosphoric acid is excreted in the feces, on the average over 40 per ct. of the nitrogen and 60 per ct. of the potash voided by farm animals is in the urine. Pound for pound, the urine has a greater

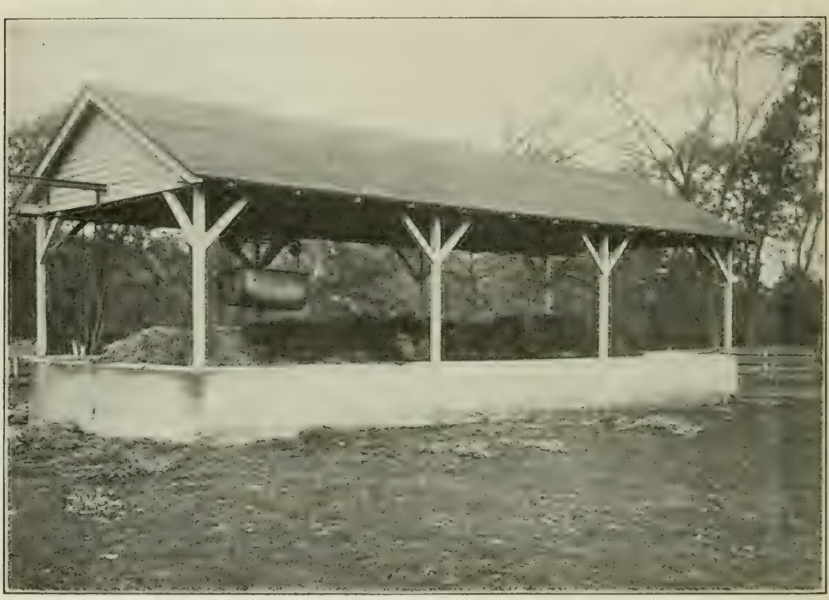

FIG. 62.—A MANURE SHED AND PIT

When manure is packed solidly in such a shed as this, with concrete foundation, there is but little loss from fermentation and none from leaching. (From *Hoard's Dairyman.*)

fertilizing value than the feces, except with the pig, which voids a watery urine. The fertility in urine is also in solution and much more readily available to plants than that in the feces. Obviously, plenty of bedding should be used to absorb this valuable fertilizer.

A manure pile under the eaves, against the side of the barn, or manure lying for months in an open barn yard, is a sight all too common on American farms. When manure is exposed to the leaching action of rains, the losses are great, even amounting to half of the total value in periods of 2 to 5 months. Unfortunately, the loss falls on the constituents which are most soluble and therefore most quickly available to plants.

Farm manure contains myriads of bacteria, molds, and yeasts, the numbers often running into billions for each gram of manure. These organisms in general break down the complex compounds of the manure into simpler ones, which are soluble. Some of these changes are advantageous, as they make the plant food more available to crops, but under improper conditions of storage much of the nitrogen in the manure may be lost thru these fermentations. When the manure is dry or loosely packed, the bacteria which thrive in the presence of air develop profusely, causing ''hot'' fermentation. In this process there is a rapid formation of ammonia from the nitrogenous compounds of the manure, much of which passes as gas into the air. The strong smell which every farmer has noticed in close horse stables is due to this escaping ammonia gas produced by the breaking down of nitrogenous compounds in the urine. In still other changes which may take place free nitrogen gas may be formed, which is likewise lost into the air. When the pile of manure is well packed and is kept damp, these changes can not go on, but only the beneficial decompositions which render the plant food more available and produce what is termed ''well-rotted manure.'' If the manure is very loose and dry, ''fire fanging,'' may occur, when the manure becomes grayish or dusty in appearance. This change, which is brought about by certain fungi or molds, seriously injures the value of the manure. Phosphoric acid and potash are not lost thru fermentation, but heavy losses may occur thru leaching.

Care of manure.—To prevent loss in manure, the urine should be saved by having tight gutters and using plenty of bedding. If possible, the manure should be drawn directly to the fields and spread each day. This is not advisable, however, in winter on very sloping land when covered by deep snow, as much fertility may wash down the hill in the spring. When manure can not be spread on the land, it should be stored, preferably under cover, in well-packed piles kept moist to prevent hot fermentation. If hogs or cattle have access to the shed, they aid in firming the pile. It is an excellent plan to mix the manure from horses or sheep, which is drier and therefore called "hot manure," with the cattle or pig manure, which contains more water. In Europe manure is often stored in pits or cisterns. When it is necessary to leave manure out of doors, the pile should be made high and compact, so that rains will not soak thru, and it should be built with the sides perpendicular and the top sloping down toward the center so that all rain will soak into the pile instead of draining off as from a stack of hay. It is impossible to prevent all waste in caring for manure, but under proper management not over 10 to 20 per ct. of the nitrogen and practically none of the phosphoric acid and potash will be lost.

QUESTIONS

1. How is the fertilizing value of feeding stuffs and farm manures computed?
2. About what part of the fertilizing constituents do mature work horses void in the manure; fattening pigs; dairy cows?
3. Give examples of feeds which are rich and of others which are low in fertilizing constituents.
4. What is the manurial value of a feed?
5. A farmer who intends to fatten some steers has on his farm shelled corn, corn silage, and clover hay. To provide a well-balanced ration, he sells 10 tons of corn and buys as much cottonseed meal as he can with the proceeds. Using local market prices and assuming that the cottonseed meal is worth enough more to him than the corn to pay for hauling, find the gain or loss in manurial value from the exchange.
6. Compare the fertility lost in selling a ton of corn and a ton of fat pigs; a ton of butter.
7. What are "hot" and "cold" manures?
8. What is the average amount of fertility in mixed farm manure?
9. How may losses occur in farm manure and how should manure be cared for to lessen loss?

PART III

FEEDING FARM ANIMALS

CHAPTER XVIII

FEEDING AND CARE OF HORSES

I. FACTORS INFLUENCING THE WORK DONE BY HORSES

While practically every farmer has horses or mules to perform work on the farm, comparatively few have large numbers. Perhaps for this reason, most of us do not realize the true rank of our horse industry. In January, 1920, there were on the farms in the United States more than 20,140,000 horses and 5,450,000 mules. In spite of the coming of the automobile, auto-truck and tractor, the number of horses on farms has increased 1.5 per ct. since 1910 and the number of mules 29.5 per ct.

To feed these work animals costs at least $2,000,000,000 each year. Yet the scientific and economical feeding of this class of live stock usually receives scant attention. Many a farmer, for example, will carefully determine which feeds furnish most cheaply a well-balanced ration for his dairy cows. But he will continue to feed his horses the usual ration in his locality, such as oats and timothy hay, no matter how expensive these feeds may be. As is shown in Chapter XIX, by careful selection of feeds for horses, it is often possible to save one-third of the feed bill, with no injury, and in some cases even a benefit to the animals.

Before a detailed study of feeds for horses and of the methods of feeding and care is begun, we will briefly consider the factors which influence the work they perform. Since 81 per ct. of our work animals are horses, the following discussions usually treat of the horse. However, the same feeds may be used for mules and the same principles of feeding and care applied.

Work done by horses.—In measuring work, the units used are the foot-pound and the foot-ton. A *foot-pound* is the amount of work done in lifting one pound one foot against the force of gravity; and a *foot-ton* the amount done in lifting one ton one foot against gravity. The rate at which work is performed is measured in terms of horse-power. A *horse-power* is the power required to lift 33,000 lbs. at the rate of 1 ft. per minute, or to lift 1 lb. at the rate of 33,000 ft. per minute. To illustrate, a horse drawing up a loaded bucket weighing 100 lbs. from a well 330 feet deep in one minute exerts a force equal to 1 horsepower.

The work which horses can do depends on their weight, muscular development, and endurance. On the average, a 1,000-lb. horse working steadily 10 hours a day can develop about 0.67 to 0.83 horse power and do 6,600 to 8,200 foot-tons of work a day. A 1,600-lb. horse will produce 1.06 to 1.33 horse power and do about 10,500 to 13,200 foot-tons of work daily. An ox can draw as heavy a load as a horse of the same weight, but ordinarily at only two-thirds the speed. A man will do about one-fifth as much work as the average horse, tho for a minute or two he can exert a full horse power or even more.

The character of the road bed is a most important factor in determining how heavy a load a horse can draw. While only 25 to 67 lbs. of draft are required to haul a load of a ton (including weight of wagon) on a good pavement, the draft on a common earth road is 75 to 224 lbs.

True value of feeds for work.—To be able to feed horses economically, it is necessary to understand the true value of different feeds for the production of work. We have learned in Chapter III that only the *net energy* of the feed can be used to produce such external work as propelling the body, carrying a burden, or pulling a load.

The most extensive investigations on the work yielded by various feeds are those of the German investigators, Wolff and Zuntz. Some of their results are presented in the following table, which shows how much work 1 lb. of different feeds may yield if fed to a horse already receiving enough to maintain his body when idle.

Possible work from 1 lb. of various feeds when fed to the horse

Feeding stuff	Crude fiber	Total digestible nutrients	Nutrients required for mastication and digestion	Net nutrients remaining	Possible work from 1 lb. of feed
	Per ct.	Lbs.	Lbs.	Lbs.	Ft.-tons
Corn	1.7	0.785	0.082	0.703	607.7
Linseed cake	9.4	0.690	0.125	0.565	488.4
Oats	10.3	0.615	0.124	0.491	424.4
Meadow hay	26.0	0.391	0.209	0.182	157.3
Clover hay	30.2	0.407	0.239	0.168	145.2
Carrots	1.6	0.113	0.021	0.092	79.5
Wheat straw	42.0	0.181	0.297	–0.116	–100.3

Fiber, the woody material of plants, is less digestible than the other nutrients and, moreover, much energy is used up in masticating and digesting feeds containing much of it. Therefore, the higher a feed is in fiber, the less work it will yield per pound. While each pound of corn yields 607.7 foot-tons of work, meadow or clover hay produces only one-fourth as much, and more energy is actually spent in digesting and masticating wheat straw than it supplies. Hence, it has a negative value for producing work, tho it may aid in keeping a horse warm. Carrots yield but a small amount of work per pound, due to their watery nature. It is clear from this table that the harder a horse works, the greater must be the proportion of concentrates, such as corn, and oats, in his ration, and the smaller the proportion of roughages, as hay and straw.

Types of work performed by the horse.—It is evident that the horse at work must receive a larger supply of nutrients than when idle, and that the amount needed will depend on the severity of the work done. Let us then consider what types of work the horse performs. His work usually consists of a more or less complex combination of the following simple kinds: (1) Locomotion, or traveling along a level course without a load; (2) raising the body, with or without a load, against the force of gravity in ascending a grade; (3) carrying a load; (4) draft, or hauling a load. A horse drawing a load up a hill combines all of these types. He is (1) advancing and at the same time (2) raising his body. Likewise, he is (3) carrying the harness and (4) hauling the load. In descending the hill the horse will be called upon to perform even a fifth type of labor, bracing himself to prevent too rapid a descent.

FIG. 63.—The conformation of the draft horse, developed by years of breeding, fits him to haul heavy loads at a relatively slow pace.

The amount of nutrients required in each of these types of work has been determined in careful experiments. However, the results are of theoretical rather than practical interest, for the work of most horses varies greatly from day to day and is usually of a complex nature, difficult to divide into these simple types. All that can commonly be done is to estimate whether the horse is performing light, medium, or heavy work, and then compute a ration which meets the standard for this degree of labor. As we have seen in Chapter VI, normally the carbohydrates and fats furnish the energy used in producing work, and no more protein is usually broken down during work than during rest. Hence, the nutrient requirements of horses at work resemble those of fattening animals. With both these classes, after growth is completed the ration may consist largely of carbohydrates and fat, with only sufficient protein to ensure complete digestion of the ration.

It is not necessary, and is often not advisable nor economical, to furnish as much digestible crude protein in the ration as stated in the Wolff-Lehmann standard. (See Appendix Table IV.) Horses at hard work have been fed for considerable periods without harm on rations having nutritive ratios as wide as 1 : 28.0 However, as shown on Page 47, when the nutritive ratio is wider than 1 : 8.0 or 1 : 10.0, the digestibility of the ration is decreased and feed is wasted.

Feeding standard for horses.—From a study of American and European investigations, the following standards have been prepared (given also in Appendix Table V), which state in simple terms the nutrient requirements of various classes of horses:

Morrison feeding standards for horses

	Per day per 1,000 lbs. live weight			
	Dry matter	Digestible crude protein	Total digestible nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	1:
Idle horses	13.0–18.0	0.8–1.0	7.0– 9.0	8.0–9.0
Horses at light work.....	15.0–20.0	1.0–1.2	9.0–11.0	8.0–8.5
Horses at medium work...	16.0–21.0	1.2–1.5	11.0–13.0	7.8–8.3
Horses at hard work.....	18.0–22.0	1.5–1.8	13.0–15.0	7.6–8.1

It will be noted that while only 4 to 5 lbs. more dry matter is advised for the horse at hard work than for one which is idle, he requires about 6 lbs. more total digestible nutrients. This means that the idle horse can be maintained on such feeds as hay alone, which is low in total digestible nutrients, and furnishes but relatively little net energy. However, the ration for the hard-worked horse must be more concentrated in character, containing a much smaller proportion of hay or other roughage. As the work becomes harder, a slightly narrower nutritive ration is advisable. The amount of protein here stated is the minimum advisable, and considerably more may be supplied if protein-rich feeds are lower in price than carbonaceous feeds.

Influence of speed on work.—The horse is at his best for drawing loads when moving at a rate of 2 to 2.5 miles per hour. If held to a slower pace and especially if urged to move faster, his efficiency decreases. When worked at the rate of 11.25 miles per hour, he accomplishes less than one-tenth of the amount of work of which he is capable. When trotting with no load the horse expends nearly twice as much energy per mile of travel as when walking. Among the reasons why more energy is required to perform a certain amount of work at a fast pace are: (1) In trotting or galloping the rise and fall of the body are much greater than in walking. Energy is wasted in these movements, and hence a smaller amount is available for onward movement. (2) At a rapid pace the work of the heart is increased, the temperature rises, and much heat is lost thru the evaporation of water from the skin and lungs in the effort to keep the body temperature normal. The proportion of the food which produces heat is thus increased, while less can be converted into work.

To keep mail-coach horses, which were pushed at top speed, in condition, they could often be worked but one hour a day, traveling only eight miles even on good roads. While a pound of additional load makes but little difference to a draft horse, with running horses the requirement of speed makes it necessary that the weight carried (rider and saddle) be as small as possible. An ounce of additional loading may make a difference of a yard or more in half a mile of running.

Influence of grade.—In going up a grade, the horse must not only propel his body and the load over the ground but must also raise them against the force of gravity. In ascending a grade of 10.7 ft. in 100 ft. the horse expends three times as much energy per mile as when traveling on a level road. The steeper the grade, the greater the energy required.

On the other hand, in going down a gentle incline, owing to the force of gravity less energy is required than on a level road, which results in a saving of nutrients. If the grade is steeper than 10 feet in 100, however, the horse must expend energy in bracing himself and the load against a too rapid descent and hence uses as much as when traveling on the level. On a still steeper downward slope more energy is expended than on a level course. Obviously, a great saving of feed may be effected by a proper use of wagon brakes in a hilly country.

II. Preparation of Feed; Water; Salt

Chaffing hay.—With horses at ordinary farm work, which have abundant time to chew their feed thoroly, cutting or chaffing hay probably does not result in sufficient saving to warrant the expense. However, in stables where large numbers of horses are kept, the hay is frequently chaffed. Somewhat less is then wasted, especially if it is of rather poor quality, and dust may be easily laid by sprinkling with water. The grain allowance is often mixed with part of the chaffed hay, which forces the horses to eat the grain more slowly and chew it more thoroly. A common practice in Europe is to mix cut straw with chaffed hay, more straw thus being eaten than would otherwise be the case.

Grinding grain.—Where oats are mixed with chaffed hay, there is no advantage in crushing the grain if the horses have good teeth. It is also doubtful if it pays to crush or grind oats when fed alone, except perhaps for hard-worked horses which have but little time in the stable, or for those which bolt their grain or have poor teeth. All small, hard grains, such as wheat, barley, rye, and kafir, should be ground or, better, rolled. Corn is preferably fed on the cob.

Soaking or cooking grain.—When such grains as wheat and barley cannot conveniently be rolled or ground, they should be soaked before feeding, to soften the kernels. Ear corn that is so dry and flinty as to injure the horses' mouths should also be soaked or ground.

The custom of cooking even a small portion of the feed given to horses has almost ceased, since experiments have shown that uncooked feed gives just as good results.

Watering the horse.—Extensive tests have shown that horses may be watered before, after, or during a meal without interfering with the digestion or absorption of the food eaten. Therefore, individual circumstances and convenience should determine the time of watering, but when a system is once adopted it should be rigidly adhered to, for a change from one system to another lessens the appetite. A horse long deprived of water or having undergone severe exertion should be watered before being fed, but it is dangerous to allow a horse much water when very warm. A moderate drink taken slowly will refresh him and do no harm.

About 10 to 12 gallons, or 100 lbs., of water should be provided daily for each horse. In warm weather and when at hard work, horses will drink more water than at other times, owing to the greater evaporation of water from the body. The nature of the feed also affects the quantity of water drunk.

Salt.—The horse shows great fondness for salt and thrives best when regularly supplied with it. A reasonable allowance is two ounces per head daily.

III. HINTS ON FEEDING AND CARING FOR HORSES

General hints on caring for horses.—There is great truth in the Arab saying, "Rest and fat are the greatest enemies of the horse." Regular exercise or work is necessary for health and a long period of usefulness. A mature horse should travel not less than 5 to 6 miles daily and the highly-fed colt should have abundant exercise. Whenever a horse is not working, reduce the grain, even to one-half, to avoid digestive troubles.

To maintain health, horses should be housed in well-ventilated quarters and be protected from drafts. Previous to 1836 the annual loss of horses in the French army was enormous. When the stables were enlarged and properly ventilated the loss was reduced to one-seventh the former figures. A cool, well-ventilated stable is far preferable to warm, close quarters.

It is important to blanket the horse in cold weather whenever his work ceases and he is forced to stand in the cold for even a short time. Thoro and careful grooming is necessary to remove the solid matter left on the animal's coat when the perspiration evaporates, and to keep the pores open and the skin healthy. This should be done with a dull currycomb, a brush being used on the tender head and legs. The horse will rest much more comfortably after a hard day's work if groomed at night. Bedding the stall well is just as important.

Fig. 64.—Speed Decreases the Work that can be Performed

A pound of additional load makes but little difference to a draft horse, but with the race horse the load must be made as light as possible. (From *Western Horseman.*)

The good horseman always cares for the teeth of his charges and sees that no sharp points and ragged edges prevent proper chewing of the food. He also sees that the collar and harness fit well and that the horses' feet are properly shod. He makes any change in the ration gradually, for a sudden change may bring on colic. In starting the day's work he gradually warms the horse to his work, so that his collar will be shaped to his shoulders, his muscles in proper trim, his bowels relieved, and breathing and heart action quickened before he is put to extreme effort. At the end of a trip or the day's work he likewise cools his horse off gradually before returning to the stable.

The work horse.—The regularity of work, feeding, and rest usually brings a long life of usefulness to the work horse. In the previous paragraphs we have discussed the principles of feeding and caring for the work horse. The amount of feed necessary will depend on the size of the horse and the nature and severity of the work. As a rule the total allowance of grain and hay should be from 2 to 2.5 lbs. daily per 100 lbs. of horse. Horses at medium to hard work will need 0.7 to 1.4 lbs. of grain per 100 lbs. live weight. The amount of grain for each horse will depend on whether he is an easy or hard keeper. In the morning feed a small amount of hay and not over one-third the daily allowance of grain. Many feed one-third the grain at morning, noon, and night, respectively, tho the mid-day meal is sometimes omitted with horses on the street all day. No roughage need be fed at noon, most of it being fed at night. To avoid digestive troubles it is imperative that the allowance of grain for horses at hard work be reduced on idle days to no more than 70 per ct. of the amount usually fed. It is best to feed on such days in place of just grain, a mixture of two-thirds grain and one-third bran.

On coming to the stable at noon, the work horse should have a drink of fresh, cool water, care being taken, if he is warm, that he does not drink too rapidly, or too much. Before going to work he should be watered again. If possible, an hour should be given for the mid-day meal and the harness removed. When the horse comes in after the day's labor, give him a drink, unharness at once, and when the sweat has dried brush him well.

Wintering the farm horse.—The farm horse when idle during the winter may be economically wintered wholly, or in part, on roughages. Such feeds as the refuse stems from clover or alfalfa hay which has been fed to dairy cattle or fattening cattle or sheep can often be fed with advantage to such horses. It is preferable to turn idle horses out daily into a lot, protected from the wind, rather than keep them closely confined. At shedding time, feed some grain even to idle horses. Light grain feeding should begin a few weeks before the spring work starts, for horses are soft after a winter of idleness.

The mule.—It is often stated that mules require less feed than horses to do a given amount of work, but there appears to be no foundation for this statement. At 3 years of age, when shedding his milk teeth, the mule is especially susceptible to digestive disorders. At other times he is an excellent feeder, as a rule being more sensible in eating and less likely to gorge himself than the horse, and hence less subject to colic or founder. The mule is not particular in his taste and consumes roughages which the horse will refuse. He also endures hot weather better, and because of the peculiar shape of the hoof and its thick, strong wall and sole is less subject than the horse to lameness of the foot. However, the lack of weight and the small size of his foot somewhat unfit the mule for heavy draft in the city, as he does not get a good hold on the pavements.

Tho the mule will endure more neglect than the horse, good care and feed will prove profitable. For feeding the mule the same feeds are available as for the horse, and the same principles apply in suiting the feed to the size of the animal and the severity of the work performed.

Fattening horses.—As the markets demand draft horses in high flesh, in certain districts their fattening has become an important industry. The horses are usually purchased in the fall after farm work is over and gradually accustomed to a heavy grain ration, getting all they will clean up when on full feed. At this time some of the heaviest feeders will consume nearly twice as much as when at hard work, or about 2 lbs. of grain for every 100 lbs. live weight. The chief concentrates used are corn and oats, often with moderate allowances of such protein-rich feeds as wheat bran, linseed meal, or cottonseed meal added to balance the ration. Clover or alfalfa hay is commonly fed, for these hays are much superior to timothy hay. In addition, silage of good quality may be advantageously fed. At the Illinois Station [1] a ration of 8.6 lbs. corn, 8.6 lbs. oats, 2.4 lbs. wheat bran, 0.4 lb. oil meal, and 13.7 lbs. clover hay gave excellent results in fattening horses. A most successful ration for 1,450-lb. horses at the Pennsylvania Station [2] was 12.3 lbs. shelled corn, 1.4 lbs. cottonseed meal, 16.9 lbs. corn silage, and 10.5 lbs. mixed hay. Horses thus fattened require about the same amount of feed as fattening cattle for 100 lbs. gain in weight.

Formerly the horses were usually allowed no exercise, great care then being necessary to avoid digestive troubles and to keep their legs from becoming stocked. Now many feeders allow the horses to run in paddocks. Due to the forced feeding, surprising gains are often secured. Instances are reported where horses have gained 4 lbs. or even more per head daily for periods of about 2 months. While at present horses must be thus fattened to bring top prices, such rapid and excessive fattening is of little benefit and may even be injurious. When put to hard work, the horse quickly loses much of the soft flesh gained by such forcing.

Feeding the carriage and saddle horse.—Style and action are of the greatest importance with these horses, economy of feeding standing second. Good drivers in this country still assert that the oat-fed horse exhibits mettle as from no other feed. Tho oats easily excel any other single grain or concentrate, there are numerous instances in which a properly combined concentrate mixture has given just as good results, as is shown in the following chapter. From 8 to 10 lbs. of oats or their equivalent, divided into 3 feeds, should suffice for concentrates, the evening meal being the largest. In case the horse is at all constipated, bran should be fed, dry or as a mash. The hay is usually fed long, for the carriage horse has ample time for his meals. From 10 to 12 lbs. of hay is a liberal allowance, bringing the total ration within 18 to 22 lbs. The carriage horse must be trim in body and so cannot consume much bulky feed, yet some roughage is always necessary. With this class of horses the feeder must also guard against feeding too large amounts of such laxative feeds as clover and alfalfa hay or bran. Carriage horses are usually overfed and exercised irregularly or too little, and mainly for these reasons their period of satisfactory service is often brief. On days when they are not driven, the usual amount of roughage may be fed but the amount of grain should be reduced.

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[1] Obrecht, Ill. Bul. 141.

[2] Cochel, Penn. Bul. 117.

Fig. 65.—Profit-Making Brood Mares and Foals

A team of such brood mares would bring added profits to many farms where no colts are now raised. They will not only raise profitable foals but will also do no small part of the farm work. (From *Breeder's Gazette.*)

Feed and care of the brood mare.—Many farmers who raise no colts would find it profitable to keep a good team of brood mares to do part of the work and also to raise colts each year. The brood mare must, however, have proper feed, care and management. Recent statistics show that only 60 per ct. of the brood mares that are bred each year produce living foals; this enormous loss is largely due to neglect and carelessness. Idleness must be avoided. Mares which work regularly are more certain to bring good foals than idle ones, yet judgment must always be used in working them. Pulling too hard, backing heavy loads, wading thru deep snow or mud, or other overexertion is dangerous. When not worked, the mare should be turned out daily for exercise. As foaling time approaches, the work should be lightened, and preferably discontinued 3 days to a week before foaling. When laid off, the mare should still be allowed exercise. Mares heavy in foal are apt to be cross and quarrelsome, but they should always be handled gently.

Feeding a working brood mare is simpler than feeding an idle one The essentials are a well-balanced ration of good-quality feeds, containing a liberal supply of protein, lime, and phosphorus, which are needed for the growth of the fetus. An abundance of these nutrients is especially needed by pregnant mares that have not yet finished their own growth, and those that are suckling foals, for there is then a double draft on the mothers. All feeds should be free from dust, mold, or decay, which might cause abortion. Mares used only for breeding purposes do well without grain when on nutritious pasture. With insufficient pasture and in winter some grain should be given. The feed should not be concentrated in character but should have considerable bulk or volume. The bowels should be kept active thru a proper combination of such feeds as bran, linseed meal, roots, etc.

Gestation period and foaling time.—The average period of gestation for the mare is about 11 months, or 340 days, tho it may vary quite widely. Shortly before foaling the grain allowance should be decreased and laxative feeds more freely used. To avoid infection which may cause navel ill and joint disease, the stall in which the mare is to foal should be thoroly cleaned and disinfected. The mare should be given a half bucket of water before foaling, and when on her feet again she will need a drink of water or, better, of gruel made from half a pound of fine oatmeal in half a bucket of lukewarm water. A light feed of bran is good for the first meal and this may be followed by oats, or by equal parts by bulk of corn and bran. After foaling the mare should be confined for a few days, her ration being simple and not too abundant. With favorable conditions, after 4 or 5 days she may be turned to pasture, and in about 2 weeks, or even before if work is urgent and the mare has fully recovered, she may go back to light work.

Only the quick-maturing draft filly should under any circumstances be bred as a 2-year-old; all others when past three. Altho the natural and customary foaling time is in the spring, when the mare must do a hard season's work or she fails to get in foal from spring service she may be bred to foal in the fall.

The foal.—The thrifty, well-fed foal should make more than half its entire growth during its first year. If stunted during this time, rarely will it reach full size. It is therefore of the greatest importance that the foal start life full of vigor and be kept growing thriftily. Immediately after birth it should take a good drink of the colostrum, or first milk, of the dam. This natural purgative removes the fecal matter which accumulates in the alimentary canal before birth. Otherwise, a dose of castor oil or a rectal injection is necessary. On account of the great danger from navel and joint disease, the stump of the navel cord should be carefully disinfected.

If the dam does not supply the proper amount of milk, feed should be given her which will stimulate the milk flow. Good pasture grass is, of course, the best, but in its absence a liberal allowance of grain should be fed. On the other hand, an oversupply of milk or milk too rich in fat may cause indigestion in the foal. The dam's ration should then be reduced and some of her milk drawn, the foal being allowed the first portion, which is the poorest in fat.

Feeding the foal.—By placing the feed box low, when 3 or 4 weeks old the foal will begin nibbling from the mother's supply and will soon acquire a taste for grain. The earlier the foals so learn to eat, the more independent they become, and the mare will then be able to do more work. Crushed oats or oatmeal, with bran, are excellent feeds, as is a mixture of 4 parts of crushed corn, 3 of bran, and 1 of linseed meal. Colts should be given good clover, alfalfa, or other legume hay as soon as they will eat it, and all the clean, pure water they want. Watchfulness should always detect the first appearance of such ailments as constipation or diarrhea. In all such troubles the food for both dam and foal should at once be lessened, since nothing assists Nature more than reducing the work of the digestive tract.

If the dam cannot furnish enough milk for the foal, cow's milk is the best substitute. The poorer the milk is in butter fat the better, for mare's milk contains only about 1.1 per ct. fat. Should the mare die or have no milk, the foal may with proper care be raised on cow's milk modified by the addition of sugar and lime water.

When the mare is worked, the foal should not follow the dam but should be left in a cool, dark stall during the day, where it will be safe and not bothered by flies. The mare should be brought to the barn to suckle the colt in the middle of the forenoon and afternoon. Allow the mare to cool off, and perhaps draw some of the milk by hand before turning her into the stall with the foal. Brood mares at work and nursing strong foals should be heavily fed to sustain a good milk flow. If the mare is worked during the day, it is well to turn both dam and foal onto grass pasture at night, and in addition feed a liberal allowance of grain.

When dams and foals are running at pasture, a pen should be made in the pasture near where the horses are inclined to loiter, building it so high that the mares will not try to jump it, and with sufficient space from the ground to the bottom rail to allow the foals to pass under. Put in a handy gate, then an ample feed trough. After the mares have eaten together in the pen a few times the foals will visit this ''creep'' regularly after their dams are shut out. To induce the dams to loiter about, keep a large lump of rock salt near by and occasionally give a feed of oats at the pen. If flies torture the foal, it is better to confine the mare and foal in a darkened stall during the day and turn to pasture only at night.

Weaning.—At from 4 to 6 months of age, the foal should be weaned. When the mare is bred soon after foaling, or if for any reason the dam and foal are not doing well, it is best to wean comparatively early. On the other hand, if the mother has a good flow of milk and her services are not needed, the foal may be allowed to suckle 6 months. If the foal has been fed increasing quantities of grain as it developed, weaning will cause little, if any, setback to either dam or foal. In parting dam and foal keep them well separated, else all must be done over again. The grain ration of the mare should be reduced till she is dried off.

The education of the colt should not be postponed until it is sought to ''break'' him as a 3-year-old, and then attempt to bring the independent animal under man's guidance all at once. The young foal should be taught to lead at the halter, stand tied in the stall, and display proper stable manners.

After weaning.—The foal should be kept growing vigorously after weaning by an ample allowance of feed. To make good bone and strong muscle, feeds rich in protein, calcium, and phosphorus should be chosen. Nothing is superior to bluegrass or other good pasture. and oats. Among the concentrates, wheat bran, cottonseed meal, linseed meal, buckwheat middlings, wheat middlings, soybeans, cowpeas, and Canada field peas are rich in protein, which goes to build muscle, and in phosphorus, needed in building the skeleton. All the legume hays--alfalfa, clover, cowpea, etc.—are rich in calcium. A combination of such concentrates and roughages as these should furnish abundant bone- and muscle-forming material. Corn, barley, kafir, milo, and emmer may be used as part of the ration, when properly balanced by protein-rich feeds. When fed large amounts of alfalfa hay, colts will relish a little timothy or prairie hay, straw, or corn fodder occasionally. If maximum growth is desired it will be necessary to feed some grain even on good pasture. The young horse which is not developing the proper skeleton may be fed substances especially rich in phosphorus and calcium, such as 2 or 3 ounces daily of tankage containing ground bone, or 1 ounce daily of ground bone or ground rock phosphate (floats).

Cost of raising horses.—According to estimates received by the United States Department of Agriculture from 10,000 farmers in various parts of the United States, the average cost of raising colts to the age of 3 years, under pre-war conditions, was $104.06. Deducting the value of the work done before the third year, the net cost was $96.54. The average selling price of the colts when three years old was $136.17. About 54 per ct. of the total cost of raising the colt was for feed, 16 per ct. for care and shelter, and the remainder for the service fee of the stallion, time lost by brood mare, veterinary services, and miscellaneous expenses. The cost varied quite widely in different sections of the country, being highest in the East.

Cost of horse labor.—The cost of horse labor is a matter of great interest and importance to all farmers, especially at the present time when tractors are competing with horses as sources of draft power. Cooper[3] found that under pre-war conditions the average costs of keeping a horse a year on certain Illinois farms were as follows: $68.75 for feed and bedding, $13.99 for labor in feeding and caring for the horse, $7.90 for interest on the capital invested in the horse, $4.95 for interest, depreciation, and taxes on stable, $3.82 for use of equipment, $.86 for shoeing, and $5.62 for miscellaneous items, including depreciation of the horse and veterinary services. This brought the gross cost to $105.89. Allowing a credit of $5.24 for the manure produced (too small a credit), made the net cost $100.65. These horses worked on the average 1,053 hours a year and were fed on the average 4,500 lbs. of concentrates (practically all corn and oats) and 1,540 lbs. of hay. In addition, 2,684 lbs. of other roughage (straw and fodder) was fed or used for bedding, and the horses were pastured on the average 148 days. The average cost of horse labor per hour was 9.56 cents. Under present conditions, tho some of the expenses of keeping horses are higher, the net cost of horse labor on these farms is probably not materially higher than this, if a fair credit is allowed for the value of the manure produced.

The stallion.—Nothing so vital to the well-being of the stallion is so commonly neglected as is proper exercise. The best exercise is honest work: there is no better advertisement of a stallion than letting him be seen at work on the road or farm. Even during the breeding season a half day's work regularly is beneficial. When real work is impossible he should travel on the road at least 5 miles daily.

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[3] U. S. D. A. Bul. 560.

The ration of the stallion should consist of first class, wholesome feeds, supplying ample protein and mineral matter for thrift and vigor. The choice of feeding stuffs will depend on the particular locality, the same principles applying as in the case of the work horse. The following concentrates are well-suited to feed with timothy hay or prairie hay: oats; oats 4 parts, corn 6 parts, and bran 3 parts by weight; oats 4 parts, corn 6 parts, and linseed meal 1 part; corn 7 parts, bran 3 parts, linseed meal 1 part. When some alfalfa or clover is fed, a smaller proportion of protein-rich concentrates is needed.

No specific directions as to the total amount of feed required can be given, since this depends on the exercise the animal gets and whether he is a "hard" or "easy" keeper. A safe rule is to keep the stallion in good flesh, but not "hog fat," for this will injure his breeding powers. Most horsemen advise that in the breeding season he be kept gaining just a bit, rather than be allowed to run down in flesh. While some recommend feeding 3 times a day, 4 is preferred by others.

QUESTIONS

1. Define foot-pound, foot-ton, and horse-power.
2. Compare the amounts of work possible from 1 lb. each of corn, oats, clover hay, and wheat straw.
3. What four types of work does a horse do?
4. Compute the cheapest satisfactory ration you can from feeds available locally for a 1,500-lb. horse at medium work. Use the method illustrated in Chapter VIII in selecting the cheapest feeds.
5. What are the effects of speed and of grade on the energy required for a given amount of work?
6. Discuss the value of chaffing hay, grinding grain, and soaking or cooking grain for horses.
7. When should a horse be watered?
8. Discuss the feeding of work horses.
9. How should idle farm horses be wintered?
10. What feeds are chiefly used for fattening horses?
11. Mention some important points to be observed in feeding and caring for carriage and saddle horses.
12. Briefly discuss the feed and care of the brood mare.
13. How would you feed a foal before and after weaning?
14. Discuss the feed and care of stallions.

CHAPTER XIX

FEEDS FOR HORSES

I. Carbonaceous Concentrates

In most localities the usual ration for horses is restricted to but one or two kinds of grain with no more variety in the roughages. Due to custom and prejudice many insist that these particular feeds are by far the most economical and satisfactory ones which can be fed. Yet in traveling from one district or country to another we find a large number of feeds all successfully used for horses. In the northern Mississippi valley the ration is quite generally corn and oats, while in the South corn is the chief concentrate, with dried corn leaves, legume hay, and other roughages. On the Pacific coast crushed barley is the common grain used, with hay from the cereals. In Europe various oil cakes and beans are often fed. In Arabia, Persia and Egypt barley is the only grain, while in sections of India, a kind of pea, called gram, is the usual food. In some districts horses are fed such unusual feeds as the leaves of limes and grapevines, the seeds of the carob tree, bamboo leaves, and dried fish.

As further shown in this chapter, a long list of feeds are well-suited to horses. Hence, to feed these animals economically, due attention must be given to the prices of the various feeds which are locally available, and a combination selected which will maintain them in good condition at a minimum expense.

Oats.—This grain, so keenly relished by horses, is the standard with which all other concentrates are compared. Oats are the safest of all feeds for the horse, due to the hull, which, tho furnishing little nutriment, gives the grain such bulk that not enough can be eaten at one time to cause digestive trouble from gorging. Oats form a loose mass in the stomach, which is easily digested, while such heavy feeds as corn tend to pack, causing colic. It does not pay to crush or grind oats except for horses with poor teeth, for foals, and possibly for horses worked extremely hard. New or musty oats should be avoided, as they may cause colic.

Substitutes for oats.—Due to the widespread demand, oats are quite commonly so high in price that they are not an economical feed. Fortunately, both science and practice show that other single grains or mixtures of concentrates may be substituted with no detrimental effects. The Arab horse, so renowned for mettle and endurance, is fed no oats, but chiefly barley. After experiments covering 35 years with over 30,000 horses, Lavalard, the great French authority on the feeding of horses, concluded that other feeds could be substituted for oats with a great saving in cost of feed and without lowering the efficiency of the horses. The many grains and by-products which may be used in place of oats are discussed in the following paragraphs. From the data there given one can easily determine what feeds are most economical for him to use, considering the local prices. In substituting other feeds for oats, due care must be taken to balance the ration to meet the feeding standards, as given on Page 224.

Fig. 66.—Oats are Unexcelled for Carriage or Saddle Horses

While oats excel any other single grain or concentrate for such horses, a proper combination of other concentrates will give just as satisfactory results.

Indian corn.—Next to oats, Indian corn is the grain most commonly used for horses in America. Millions of horses and mules derive their strength from this grain, never knowing the taste of oats. Because it costs less and has a higher feeding value than oats per 100 lbs., it is extensively used where large numbers of horses must be fed economically. As corn is a heavy, highly-concentrated feed, care must be taken to limit the amount fed to the needs of the animal.

When corn forms a large part of the concentrate allowance, the ration should be balanced by concentrates or roughages rich in protein and mineral matter, in which this grain is deficient. With legume hay, which supplies the lacking protein and ash, for roughage, corn may be successfully fed as the only concentrate to mature horses at general farm work. Such an unbalanced ration as corn and timothy or prairie hay, all feeds low in protein, is not satisfactory. This is shown by the following results secured at the Kansas Station[1] with 1,150-lb. artillery horses, performing more severe labor than the average farm horse.

Corn and carbonaceous hay requires supplement

Average ration	Gain or loss in weight Lbs.	Nutritive ratio	Daily cost of feed per 1,000 lbs. live weight Cents
Lot I			
Oats, 12 lbs. Prairie hay, 14 lbs.	16.3	1:7.9	20.3
Lot II			
Shelled corn, 12 lbs. Prairie hay, 14 lbs.	—29.3	1:11.5	17.5
Lot III			
Shelled corn, 6 lbs. Wheat bran, 3 lbs. Linseed meal, 1 lb. Prairie hay, 14 lbs.	3.9	1:8.4	16.7

In winter, when the weather was cold and the work moderate, there was no apparent difference between the horses in Lots I and II. However, as the weather grew warmer and the work more severe, the horses in Lot II, fed the unbalanced ration of corn and prairie hay, lost weight, tho their endurance, wind and spirit were not injured. The well-balanced ration fed Lot III was fully as satisfactory as the oat ration and cheaper than even the straight corn ration. Similar results were secured in France with 17,000 army horses. Tho the officers were at first prejudiced against corn, they finally had to admit that when it formed a large part of the concentrates the horses showed as much energy and vigor as those fed oats, with no more sickness. The objections often raised that horses fed corn lack nerve and action, sweat easily, and wear out earlier are probably due to feeding too heavy an allowance of this grain or failure to balance the ration properly.

Thruout the corn belt the grain is usually fed on the cob or shelled. Ear corn is safer to feed than shelled for it keeps better, and the horse eats it more slowly, chewing it more thoroly. If corn is ground for horses with poor teeth or those working long hours, it should be ground coarsely, for fine meal forms a mass in the stomach which is difficult to digest and may cause colic. Changes from oats or other feeds to corn should be gradual. New corn may produce indigestion.

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[1] McCampbell, Kan. Bul. 186.

The other cereals.—On the Pacific coast, and in Europe, Africa, and many parts of the Orient, *barley* is extensively fed to horses. Ground barley is slightly more valuable than ground oats. While the high price of sound *wheat* usually prohibits its use for stock feeding, damaged grain may be fed to horses with economy, if not moldy. Only moderate amounts should be fed and the crushed wheat should be mixed with a bulky concentrate like bran or with chaffed hay or straw, to avoid digestive disturbances, as it tends to pack in the stomach. *Rye* may also be used for horses, the same precautions being taken to prevent digestive trouble as with wheat. Since these grains are hard and small, they should be crushed or rolled. If finely ground they form a pasty, unpleasant mass when mixed with the saliva in the mouth.

In the southwestern states, *kafir, milo,* and the seeds of other sorghums are extensively used for horse feeding. Being small and hard, they should be ground or chopped. They may also be fed unthreshed in the head along with the forage.

Miscellaneous carbonaceous concentrates.—Thruout the sugarcane districts *cane molasses* is often the most economical source of carbohydrates for work animals. On 47 plantations, employing over 5,000 work animals, chiefly mules, an average of 9.5 lbs. of molasses was fed per head daily with excellent results. The molasses was usually mixed with the concentrates or with cut hay, but was sometimes fed in troughs or poured on uncut roughage. When molasses is higher in price than oats or corn it is not economical to feed it in any large amount, tho a quart or so a day may often be profitable as an appetizer for horses out of condition.

As *beet molasses* is very laxative, not over 4 to 5 lbs. should be fed per head daily to draft horses, and but 2.5 lbs. to driving horses. In these amounts and thinned and mixed with other feed, it is well liked by horses and has given excellent results. *Molasses feeds* of good quality are satisfactory for horses, when economical in price.

Rough rice is an economical and satisfactory feed for horses and mules in the southern states, when low in price compared with the other cereals.

Dried beet pulp is often refused by horses when fed alone, but may be used as a portion of the ration when mixed with other concentrates.

II. PROTEIN-RICH CONCENTRATES

Wheat bran.—Bran is one of the most useful feeds for horses, because of its bulky nature and mild laxative properties. If not more freely provided, its use once a week, perhaps in the form of a mash, is desirable. As the immediate effect of a bran mash is somewhat weakening, it should be given at night and preferably before a day of rest. When low in price, bran may be profitably fed in larger amounts as a partial substitute for oats. Fed with timothy hay, a mixture of equal weights of bran and corn has been found equal to one of half oats and half corn.

Wheat middlings; shorts.—Due to their heavy, concentrated nature, middlings or shorts should be fed to horses only in small amounts and mixed with bulky concentrates or chaffed roughage. Without these precautions the danger from colic is great, especially with some horses.

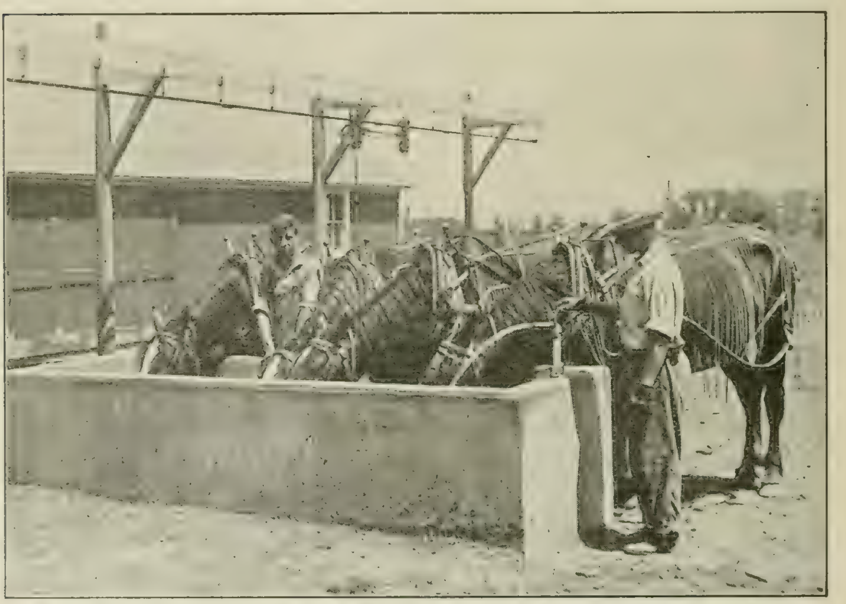

Fig. 67.—Good Care and Management Are as Necessary as Proper Feed

Regularity in working, watering, and feeding horses, housing them in well-ventilated stables, and caring for them intelligently go far toward ensuring a long life of usefulness. (From *Prairie Farmer.*)

Dried brewers' grains.—Before the advent of national prohibition, dried brewers' grains, which are satisfactory for horses, could often be substituted for oats with profit. A New Jersey market gardener saved $150 a year in feeding 8 horses on using dried brewers' grains in place of oats, with corn and hay. Dried brewers' grains are about equal to oats. Not being especially palatable, they should be mixed with other concentrates.

Linseed meal.—Linseed meal, rich in protein and having tonic and somewhat laxative properties, is an excellent supplement for rations poor in protein. Not over 1 to 1.5 lbs. per head daily is ordinarily fed, due both to its high price and its laxative effect. Linseed meal is useful for bringing into condition rundown horses with rough coats, and gives bloom and finish in fitting horses for show or sale.

Cottonseed meal.—While it is unsafe to feed large amounts of cottonseed meal to horses, good results are secured when this feed is properly used. Being a heavy feed and not particularly relished by horses, it should be mixed with better-liked bulky concentrates, such as whole or crushed oats, dried brewers' grains, or corn-and-cob meal. It may also be sprinkled on silage or on moistened hay or stover. A safe rule is to feed not over 0.2 lb. of cottonseed meal for every 100 lbs. live weight of animal, distributed over 3 daily feeds. Horses should be accustomed to the meal gradually, not over one-fourth pound being given at each feed for the first 2 or 3 weeks.

Leguminous seeds.—Like the horse bean and other beans so widely fed in Europe, the field pea in the northern states and the cowpea and soybean farther south are useful in balancing rations low in protein. All should be ground, and, on account of their wealth of protein, should never be fed as the sole concentrate.

Miscellaneous protein-rich concentrates.—Various *oil cakes* and *meals,* such as peanut, cocoanut, sunflower seed, and rapeseed meal, are fed to horses in Europe in quantities of 2 to 4 lbs. per head daily with good results. *Dried distillers' grains* have given excellent results when forming one-fourth of the concentrate allowance. *Tankage* and *blood meal* are useful for rundown horses, 1 to 2 lbs. of tankage or 1 lb. of blood meal being fed.

III. CARBONACEOUS ROUGHAGES

Too much roughage injurious.—While the horse cannot live on concentrates alone, even on oats with their strawlike hulls, too much roughage is also injurious. On account of the small capacity of his stomach, we cannot expect the horse at work to secure most of his nourishment from roughages. Thru carelessness or mistaken kindness, the mangers are often kept filled with hay. The horse may then eat far too much, with digestive disturbances, labored breathing, and quick tiring as the results. There should always be a definite, limited allowance of hay, fed mostly at night when there is ample time for mastication and digestion.

Timothy hay.—Altho not rich in digestible nutrients, timothy hay is the standard roughage for the horse thruout the northeastern United States. Its popularity is due to its freedom from dust, its palatability, and the fact that it can be secured on almost any market. While timothy cut too green makes "washy" hay, it should not be allowed to stand until it becomes woody and indigestible. A reasonable allowance of timothy hay is 1 lb. daily per 100 lbs. of animal.

Cereal hay.—On the Pacific coast, especially in California, the cereal hays—barley, wild oat, wheat, etc.—are extensively employed as roughages for horses, and in the Rocky mountain region oat hay is of considerable importance. Hay from the cereals can often be advantageously employed in many other sections of the country, as it is fully equal to timothy.

Other carbonaceous hays.—*Prairie hay* from the wild grasses is an excellent roughage for the horse thruout the western states, being but slightly less valuable than timothy. *Brome hay,* a common roughage in the northern plains region, is fully equal to timothy. *Millet hay* from Hungarian grass, Japanese millet, etc., can often be fed advantageously to horses. The amount should be limited and it should be fed with grain and preferably with other roughage, as otherwise serious kidney trouble may result. *Bermuda hay* and *Johnson-grass hay* are southern roughages well suited to horses and equal to timothy in feeding value.

Corn fodder and corn stover.—Thickly grown fodder corn and corn stover, when properly cured and cared for, are among the best of roughages for the horse, for they are palatable and usually quite free from dust. For stallions, brood mares, idle horses, and growing colts good corn forage is usually an economical substitute for timothy hay. In a trial at the New Hampshire Station [2] corn stover was successfully used as the only roughage for farm horses doing light work in winter. When the yield and feeding value of fodder corn are compared with that of the timothy hay from a like area, the usefulness and economy of this much neglected forage are apparent.

Sorghum fodder or hay.—Forage from the sweet sorghums, when properly cured, is superior to corn forage for horses. It usually deteriorates rapidly in value after midwinter unless well cured and kept dry. Moldy, decayed sorghum forage is especially dangerous to horses. Kafir, tho not so palatable as the sweet sorghums, is extensively and profitably used in the southwestern states.

Straw.—Owing to its large content of fiber and consequent low value for the production of work, but little straw can be fed to hard-worked horses. On the other hand, horses doing little or no work and

[2] Burkett, N. H. Bul. 82.

having ample time for chewing and digesting their feed may be wintered largely on bright straw instead of costly hay. Farm horses should not be wintered in the barnyard on straw and corn stover only, without grain, for they will then be in no condition for the severe work of spring. The saving thru the use of straw and other cheap roughages is well shown in a trial at the Michigan Station,[3] where the cost of feed for horses doing moderate work during the winter was 29.6 cents per head daily when fed timothy hay and oats. When shredded corn stover and oat straw was substituted for three-fourths of the timothy-hay, and roots, ear corn, and a mixture of equal parts of bran, dried beet pulp, and linseed meal replaced most of the oats, the feed bill was lowered over 40 per ct. and the horses better maintained their weights.

FIG. 68.—MULES AT WORK ON A CORN BELT FARM

The mule is the chief work animal on southern farms and is increasing in popularity in the corn states.

Carbonaceous roughages require supplement.—It is important to remember that hay from the grasses, corn fodder and stover, sorghum and kafir forage, and straw, are all low in protein. Therefore, when these roughages are fed with such grains as corn, barley, wheat, and kafir, some protein-rich concentrate should be added to balance the ration.

[3] Norton, Mich. Bul. 254.

IV. Legume Hay

Legume hay.—When given in moderation, well-cured legume hay can be satisfactorily fed to horses. The widespread prejudice against legume hay for horse feeding is largely due to these rich roughages having been fed to excess or to the poor quality of the hay used. Since alfalfa and clover hay are more like concentrates in nature than is timothy hay, less should be fed to replace a given amount of timothy. Horses are especially fond of good legume hay and must not be allowed to eat all they desire. It is important that legume hay for horses be bright and well-cured, for that which is loaded with dust and otherwise injured in quality may cause heaves. The following statements regarding clover and alfalfa hay will apply in general to hay from other legumes, such as cowpeas and lespedeza.

Clover hay.—Because clover hay is often carelessly made and loaded with dust, it is disliked by many horsemen, particularly for feeding roadsters. This objection does not apply to clean, properly-cured clover hay. For driving horses, clover hay may be mixed with timothy hay or bright straw, while for horses at ordinary farm work it may form the only roughage. The value of this hay for farm horses is shown by a trial at the Illinois Station[4] with 6 teams of 1,400-lb. horses, one in each team getting clover hay and the other timothy, with the results shown in the table.

Clover vs. timothy hay for horses

Average ration	Gain in weight Lbs.	Daily work Hours
Clover-fed horses		
Corn, 6.9 lbs. Oats, 7.3 lbs. Oil meal, 0.46 lb. Bran, 0.61 lb. Clover hay, 15.6 lbs.	15.5	7.3
Timothy-fed horses		
Corn, 6.8 lbs. Oats, 7.2 lbs. Oil meal, 0.53 lb. Bran, 0.60 lb. Timothy hay, 15.6 lbs.	3.0	7.3

Altho most of the teamsters were prejudiced in favor of timothy hay at the beginning, they later reported that they could observe no difference in the spirit of the horses or their ability to endure hot weather.

Alfalfa hay.—On thousands of farms and ranches thruout the West, alfalfa hay is the only roughage fed horses. Its use is also rapidly increasing in other sections of the country with the spread of alfalfa growing. Alfalfa hay for horses should be free from dust or mold and should not be cut until fairly mature, as hay cut at the stage usually advised for cattle is too "washy" for horses. The allowance of alfalfa hay should always be limited, not over 1.2 lbs. daily per 100 lbs. live weight being given work horses, for when too much of this protein-rich food is eaten not only is the stomach overdistended but the kidneys are overworked in excreting the large excess of nitrogenous material.

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[4] Obrecht, Ill. Bul. 150.

That alfalfa hay may be used successfully even for horses doing hard work at a rapid pace is shown by a trial with artillery horses carried on by the Kansas Station.[5] These horses worked harder than the average farm team does thruout the year, performing a considerable part of their work at the trot and no small part at a gallop. One lot of horses was fed alfalfa hay and another timothy hay, with the results shown in the table.

Alfalfa vs. timothy hay for horses

Average ration		Av. gain or loss per head Lbs.	Daily cost of feed per 1,000 lbs. live weight Cents
Alfalfa-fed horses			
Shelled corn, 8 lbs. Oats, 2 lbs.	Alfalfa hay, 10 lbs.	25.6	12.95
Timothy-fed horses			
Corn, 4 lbs. Oats, 8 lbs.	Timothy hay, 14 lbs.	—7.7	19.21

The alfalfa-fed horses, getting 2 lbs. less grain and 4 lbs. less hay than those fed timothy, showed no shortness of wind, softness, or lack of endurance and gained in weight while the others lost. The cost of the alfalfa-hay ration was only about two-thirds that of the timothy-hay ration. Alfalfa with no grain, but often with an unlimited amount of straw, is a common ration for idle horses thruout the West.

Alfalfa meal.—When good quality alfalfa hay is available it is not economical to pay a higher price for alfalfa meal, for horses waste but little of such hay when properly fed. Moreover, alfalfa meal is dusty and disagreeable to handle, and while the dust may be laid by wetting this takes considerable time.

V. Pasture and Other Succulent Feed

For horses receiving but little exercise succulent feeds are especially beneficial on account of their "cooling," laxative effect. A limited amount of succulent feed is often employed thruout the year in Europe for work horses and even for drivers.

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[5] McCampbell, Kan. Bul. 186.

Pasture.—Horses at pasture not only obtain succulent feed, but must exercise to secure it. Good pasture will maintain idle horses satisfactorily; for those at hard work pasture without grain is insufficient. Not only do the various tame and wild grasses furnish pasture for horses but as these animals are not subject to bloat they may graze the legumes as well. City horses are often turned on pasture so that their feet may recover from the ill effects of hard pavements.

Corn silage.—Until recent years little corn silage has been fed to horses and mules, but it is now being used with success on many farms. It should not be the only roughage but should serve as a partial substitute for hay. While horses at hard work can not consume much silage, because of its bulky nature, it is well suited to idle horses, brood mares, and growing colts. Since poisoning may result from feeding moldy silage to horses, only that of good quality should be used, and this fed under intelligent supervision.

Roots; tubers; fruits.—The only importance of roots for horse feeding in most sections of this country is as an aid to digestion, for the cereals generally furnish nutriment at lower cost. Carrots, especially relished by horses, are great favorites with horsemen when cost of keep is not considered. It requires about 350 lbs. of carrots or 400 lbs. of rutabagas to replace 100 lbs. of good meadow hay. Potatoes may be fed, cooked or raw, in amounts up to 17.5 lbs. per head daily. Fresh fruit may sometimes be profitably fed in moderate amounts when there is no market for it, and dried fruits, slightly injured and thereby unsalable, have been successfully used for horses.

QUESTIONS

1. How should corn be used for horse feeding?
2. What is the value of the other cereals for horses?
3. Name and tell the value of other carbonaceous concentrates suitable for horses.
4. Discuss the use and value of at least six protein-rich concentrates suitable for horses. Which are used most commonly in your section?
5. Why is timothy hay a favorite for horses?
6. What is the value of cereal hay, prairie hay, brome hay, millet hay, Bermuda hay, and Johnson-grass hay?
7. Discuss the use of corn fodder and stover, sorghum fodder, and straw.
8. What precautions should be observed in feeding legume hay to horses?
9. Show by examples how clover or alfalfa hay may be substituted for timothy hay.
10. Discuss the value for horses of succulent feeds—pasture, corn silage, and roots.

CHAPTER XX

FEEDING AND CARE OF DAIRY COWS

I. The Dairy Cow as a Producer of Human Food

As the price of land, labor, and feed increases, the dairy cow will more and more displace the strictly meat producing animals, for she produces human food far more economically than does the steer, sheep, or pig. That this change is already taking place is brought out by recent census statistics. The number of dairy cows in the United States has continued to increase, even tho the number of some other classes of stock has decreased.

Fig. 69.—Tilly Alcartra, the Holstein cow which held the world's record for milk production. The milk cans represent her average weekly production, 68 gallons. Her year's record was 30,451.4 lbs. of milk. (From *Country Gentleman*.)

Cow and steer compared.—The great economy with which the dairy cow converts the products of the fields into human food is evident from the fact that she yields in her milk 18 lbs. or more of edible solids for every 100 lbs. of digestible matter in her feed. This is over 6 times as much human food as is produced by a steer from the same amount of feed. (See Chapter VI.)

A dairy cow producing 1 lb. of butter fat per day uses about 47 per ct. of her food for the support of her body, 24 per ct. in the work of converting food nutrients into milk, and actually yields in her milk about 29 per ct. of the digestible nutrients in her feed.[1] This shows her to be a more efficient machine than either the horse or the steam engine. (See Chapter VI.)

Dairy vs. beef type.—When in full flow of milk, a high-producing dairy cow is generally spare and shows an angular, wedge-shaped form, a roomy barrel, spacious hindquarters, and a large udder. This conformation is in strong contrast to that of the low-set, blocky, beef animal, with its compact, rectangular form, and broad, smooth back. These two types are the result of careful breeding with opposite objects in view. The beef animal has been developed to store in its carcass the largest possible amount of meat. On the other hand, for generations the dairy cow has been bred for the primary object of producing large yields of milk and butter fat. As a result, tho a good dairy cow will put on flesh when she is dry, the impulse to milk production is so strong when she is in milk that even under liberal feeding she shows little or no tendency to fatten but uses all the surplus feed above maintenance for the manufacture of milk.

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[1] Haecker, Minn. Bul. 140.

In view of the widely differing nature of milk and flesh production, it is not surprising that both can not be developed to the highest degree in the same animal. As a rule, the most perfect beef cows are not economical milkers, and the best dairy cows are not satisfactory beef makers. In a trial at the Minnesota Station[2] cows of the beef type required 47 per ct. more feed per pound of butter fat produced than those of good dairy type. Cows which are not of the beef type, but yet lack in depth of body, are also not generally economical pro-

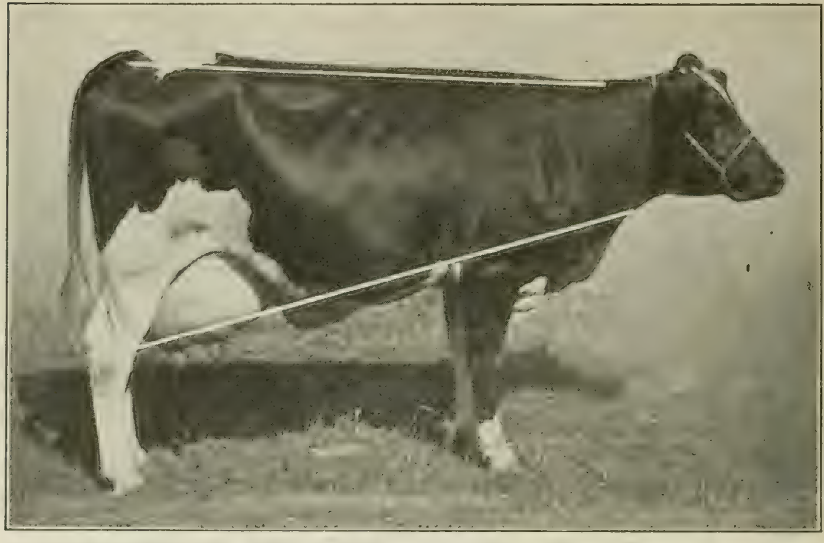

FIG. 70.—THE DAIRY TYPE AND THE BEEF TYPE ARE WIDELY DIFFERENT

A high-producing dairy cow is generally spare and angular and shows a wedge-shaped form, viewed from the side, from the front, or from the top of the withers. She has a roomy barrel, spacious hindquarters, and a large, well-shaped udder. (From Humphrey, Wisconsin Station.)

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[2] Haecker, Minn. Bul. 35.

ducers, for they cannot consume enough feed to make a large yield of milk possible.

The superiority of cows of the dairy type is further shown by the "cow censuses" conducted by Hoard's Dairyman on farms in many states.[3] Data from over 17,000 cows showed that the annual yield of butter fat by those of good dairy type was 189 lbs., compared with 138 lbs. for those lacking dairy type. Yet, the annual cost of feed was but $1.94 more for the good cows. While the cows lacking dairy type returned only $2.03 each per year over the cost of their feed, those of good dairy type brought in $17.38 over cost of feed.

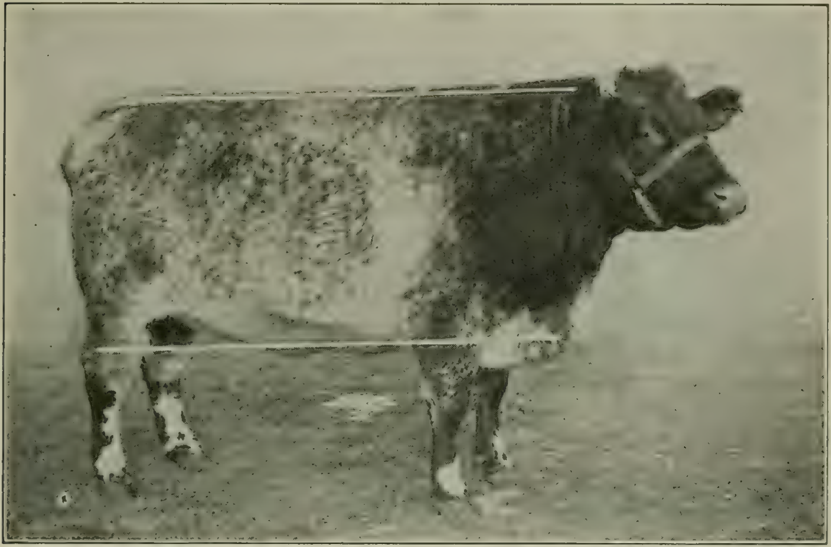

FIG. 71.—THE BEEF TYPE, WITH COMPACT, RECTANGULAR FORM

The beef type is the result of careful breeding to secure an animal which will store in its body the largest possible amount of high-priced meat. This beef cow has the low-set, blocky, rectangular form, and broad, smooth back of the beef type. (From Humphrey, Wisconsin Station.)

Good and poor producers.—Cows producing a large amount of milk and butter fat will naturally eat more feed than those yielding less, just as hard-worked horses require more than those at light work. However, the yield of the high-producing cows is so much larger that it more than offsets the higher cost of their feed. They therefore produce milk and butter fat much more cheaply than the poorer cows.

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[3] Compiled in U. S. Dept. Agr., Bur. of Anim. Indus., Bul. 164.

The relative profits from good and poor producers are well shown by trials at the Connecticut (Storrs) Station[4] where for 5 years the cost of feed and the yield of milk and fat for the 5 best and the 5 poorest cows in the Station herd were compared. The average annual cost of feed for the best cows was $57.81 per head, over $8 more than for the poorest cows. But the best cows averaged 360 lbs. of butter fat per year and returned $39.67 each over the cost of feed, while the poorest cows averaged 215 lbs. of fat and returned only $7.44 over the cost of the feed. The feed-cost of 1 lb. of fat was 23.6 cents with the poorest cows, and but 16.2 cents with the best ones. The comparison would be even more striking were it not for the fact that these "poorest cows" were really better producers than the average cows on American farms. For the first two years of the trial the 5 poorest cows did not pay for their feed, but by gradual selection the herd was so improved that during the last year the 5 poorest cows returned $17.67, on the average, above the cost of feed.

Weed out unprofitable cows.—Even in the leading dairy states, probably one-fourth or more of the dairy cows fail to pay for their care and feed, due chiefly to the fact that the owners do not know which return a profit and which are "boarders." Tho good producers are usually of the dairy type and poor producers are not, even experts are often unable to tell from appearance whether a cow is profitable or not. The only reliable way of finding this out is from records of the actual amount of milk and fat she yields.

Fortunately, such records may now be easily secured by the use of the milk scales and the Babcock fat test. Knowing the production of each cow and the approximate amount of feed she has consumed in a given period, the dairyman can discard the unprofitable animals, and gradually build up a herd of high producers at small expense by using a bred-for-production sire and keeping all heifer calves from the best cows. By this means the average yield of fat for the herd can be gradually increased year by year, until it is raised to 250 lbs., later to 300 lbs., and then even higher. As good cows sometimes have "off years" in production, animals should not be discarded after a single year's trial if there is good reason to believe they will do better in the future.

Keeping records of production.—The most satisfactory way to find out the value of each cow is to weigh and record each milking from every animal. This does not require much work, if a convenient spring balance and handy milk sheets for entry of the records are provided. For determining the fat content of the milk, it is sufficient to take a sample covering 3 to 5 days of each month. Reasonably accurate records may be obtained by weighing and sampling the milk of each cow regularly on 3 consecutive days each month thruout the year. The average yield of milk and fat for this period is taken as the average for the month. Another method of less value, but better than no testing, is to record the production of each cow for 7 consecutive days at intervals of 3 months. Tests covering only a week or even a month of the year are unreliable, for cows differ widely in persistence of milk yield. A cow which gives a good flow of milk for a time but goes dry relatively soon may be much less profitable than a persistent milker that never yields as much fat in any one week as does the first cow.

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[4] Beach, Conn. (Storrs) Bul. 29.

Cow-testing associations.—The remarkable development of dairying in the Scandinavian countries of northern Europe has been largely due to the work of cow-testing associations. In these organizations a trained tester is employed, who spends a day every month with each of the herds in the association. Arriving on the farm in the afternoon he weighs and samples the milk from each cow at milking time. He furthermore weighs the concentrates given each cow and also the roughage which several get and then estimates the approximate amount given to each cow in the herd. The following morning this is repeated, after which the samples of milk are tested for butter fat. From this day's record he computes the milk and fat production and cost of feed for each cow for the current month. While such records are not as exact as if every milking were weighed, careful studies have shown the results to be within 2 per ct. of the actual production of the cow. The tester also studies the local feed market and aids the dairyman in working out economical rations. Many dairymen who would not test their herds themselves are glad to secure this service at small expense as a member of the association. The improvement wrought by these associations is marvelous. In Denmark, largely due to their work, the average annual yield of butter per cow has increased from 112 lbs. in 1884 to 224 lbs. in 1908. Cow-testing associations are now increasing rapidly in the United States and have already accomplished much good. The first association in this country was organized in Michigan in 1905. During the first 8 years the average yield of butter fat per cow in 7 herds which had been in the association from the beginning, was increased from 231.1 to 284.7 lbs., and the average net returns over cost of feed were more than doubled.

Official tests and advanced registry of dairy cows.—The establishment by the dairy breed associations of advanced registers for pure-bred cows is another important development of the dairy industry. Cows are entitled to advanced registry only when their yield in tests conducted by representatives of the state experiment stations or of the breed associations has reached a standard set by the association. Entry in these registers increases the money value, not only of the given cow, but also of her relatives, for progressive breeders in buying animals now rely more and more on records of production and less upon show-ring successes.

Records of great cows.—Thru skilled breeding combined with expert feeding, truly marvelous records of dairy production have been secured. The world's records have been steadily raised during recent years until now Duchess Skylark Ormsby, a 5-year-old, pure-bred Holstein, has produced 1,205.09 lbs. of butter fat in a single year, and Tilly Alcartra, another Holstein, holds the record for milk production, with 30,451.4 lbs. of milk to her credit in one year when a 5-year-old. These records, thought impossible a few years ago, show how far the breeding and feeding of dairy cows has advanced.

II. Factors Influencing the Composition and Yield of Milk

Composition of milk.—The milk of different breeds of cows and even of individual cows of the same breed varies quite widely in composition. While the fat content may range from less than 3 per ct. to 7 per ct. or over, there is much less range in the other constituents. The milk sugar commonly ranges from 4 to 5 per ct., the casein from 2 to 3 per ct., the albumin from 0.4 to 0.9 per ct., and the mineral matter from 0.6 to 0.9 per ct.

The average composition of milk from the different breeds is shown in the following table:[5]

Composition of milk of different breeds

Breed	Total solids Per ct.	Fat Per ct.
Jersey	14.70	5.35
Guernsey	14.71	5.16
Devon	14.50	4.60
Shorthorn	13.38	4.05
Brown Swiss	13.27	4.24
Ayrshire	12.61	3.66
Holstein-Friesian	11.85	3.42

The Jerseys and Guernseys give the richest, and Ayrshires and Holstein-Friesians the poorest, milk. However, the breeds which give the richest milk usually yield a smaller quantity, so that the total amount of fat and total solids is nearly the same for all dairy breeds. Not only does the composition of milk depend on the breed but it is also influenced by the several factors discussed in the following paragraphs.

[5] Chiefly from Wing, Milk and Its Products, p. 33.

Influence of individuality.—Cows of the same breed differ one from another, both in the amount of milk they produce and in its composition, especially the percentage of fat. Indeed, cows of the same breed may yield milk differing as much in fat percentage as the average differences between the several breeds. The milk from an individual cow may also vary considerably in fat percentage from day to day, due to changes in health, change of milkers, excitement, variations in weather, and, in small degree, to changes in feed.

First and last drawn milk.—The first milk drawn from the udder is very poor in fat, each succeeding portion increasing in richness. In a trial at the New York (Geneva) Station [6] the first portion of milk drawn from a Guernsey cow contained but 0.76 per ct. fat; the second, 2.60 per ct.; the third, 5.35 per ct.; and the last 9.80 per ct. The percentages of casein and albumin vary but little, decreasing slightly as the milk becomes richer in fat.

Effect of period between milkings.—When the intervals of time between milkings are unequal, cows generally yield a smaller amount of milk after the shorter period, but this milk is slightly richer in fat and total solids. For this reason the evening milk is usually richer than that drawn in the morning. Where the intervals are equal there is no regular difference in quality with cows milked twice a day. When they are milked 3 times daily the mid-day milking is usually the richest.

Effect of age.—The richness of milk yielded by cows remains practically constant until after the third lactation period, after which there is a slow, gradual decline in fat percentage. The total yield of milk and fat by a heifer normally increases until she is 5 years old. A 2-year-old may be expected to give about 70 per ct. as much milk and fat as when mature, a 3-year-old about 80 per ct., and a 4-year-old about 90 per ct. A cow may make her best record when 10 or 11 years old, altho she usually does her best somewhat earlier. Cows that breed regularly, usually show no marked decline in yield until at least 12 years old.[7]

Effect of advancing lactation.—For a few weeks after freshening cows usually give somewhat richer milk than during the following month or two. The fat percentage then remains fairly constant until toward the close of the lactation period, when it gradually increases. The most marked effect of advancing lactation is upon the yield of milk. In well-managed herds the normal monthly shrinkage in milk flow is about as follows: From the second to the seventh month the shrinkage varies irregularly, ranging from 4 to 9 per ct. per month, based on the yield of the given cow for the previous month. The average monthly decrease during this period is about 6 to 7 per ct. After this the decrease becomes more rapid, being 9 to 11 per ct. for the eighth month, 12 to 18 per ct. for the ninth month, and 12 to 23 per ct. for the tenth month, after which the cows are generally dried off. The farther advanced a cow is in lactation, the larger is the amount of feed required for 100 lbs. of milk or fat.

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[6] Van Slyke, Jour. Am. Chem. Soc., 30, p. 1173.

[7] Eckles, Dairy Cattle and Milk Production, p. 153.

Influence of condition at calving.—When a good dairy cow calves in a fat condition she will often yield milk containing 1 to 2 per ct. more fat than normal, losing markedly in weight meanwhile.[8] This is due to her strong dairy temperament, which impels her to withdraw fat from her body and put it into her milk. The yearly yield of fat may thus be increased by having cows calve in good condition. Also, when a cow calves in high condition, a seven-day record of fat production secured shortly after calving is no index to her ability as a long-time producer. Yearly records are therefore far more reliable guides to the value of dairy cows.

Influence of feed on richness of milk.—Until recent years it was believed that milk varied in percentage of fat from milking to milking, according to the daily feed and care the cow received. We now know that if the cow receives sufficient nutrients to maintain her body weight, the percentage of fat can not be materially altered for any long period of time by greater or less liberality of feeding or by supplying any particular kind of feed. Cows starved or greatly under-fed may produce milk somewhat poorer in fat than normal. In some experiments adding to the ration palm-nut meal, cocoanut meal, or fats, such as cottonseed oil, linseed oil, or corn oil, has slightly increased the percentage of fat in the milk for 2 or 3 weeks, after which it again became normal. In other cases, feeding fat did not even temporarily increase the richness of the milk. Conflicting results have also been secured in trials where cows were fed more protein than actually required for body maintenance and milk production. Even where improvement resulted from feeding a large amount of protein, the richness of the milk was increased by only one or two-tenths of one per ct.

The Jersey cow gives milk relatively rich in fat, and the Holstein milk that is relatively low in fat. No kind of feed or care will cause the Jersey to give milk like that of the Holstein, or the reverse. Were a piece of skin, clothed with yellow hair, taken from the body of a Jersey cow and grafted on the body of a Holstein cow, we should expect the grafted portion to continue growing yellow, Jersey-like hair. In the same way, were it possible to graft the udder of a Jersey cow on to the body of a Holstein, we would then expect the Holstein to give Jersey-like milk. It is not the feed, nor the body, nor the digestive tract of the cow, but the glands of her udder, which determine the characteristics of the milk yielded by each individual. After all, this is what we should expect, for if milk varied with every slight change of food and condition, the life of the young, dependent on such milk, would be in constant jeopardy.

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[8] Woll, Wis. Rpts. 1902, p. 117; 1903, p. 115; Eckles, Mo. Bul. 100.

While the kind of feed given the cow does not materially change the percentage of fat in her milk, in some cases it does alter the character or nature of the fat. The fat of milk is composed of several kinds of fat—palmitin, olein, stearin, butyrin, etc. When a cow is given feeds rich in vegetable oils (which contain much olein), the milk fat will then contain more olein than normal. This usually tends to make the butter softer, for olein is a liquid fat, but in some instances this tendency is offset by still other changes in the composition of the fat. Cottonseed and cocoanut meal produce firm, hard butter. A change from dry feed to pasture generally produces fat higher in olein, resulting in softer butter.

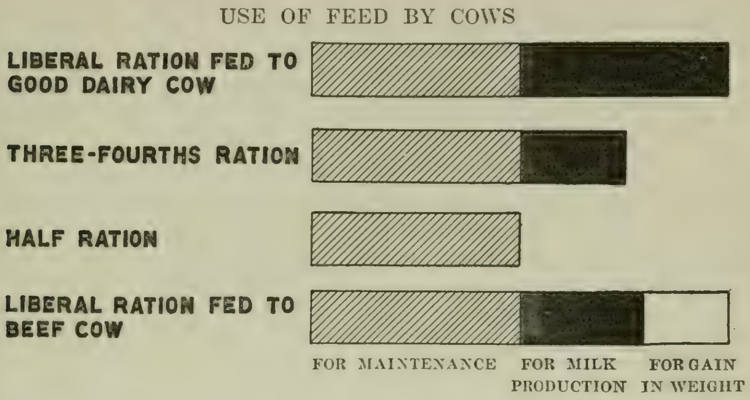

FIG. 72.—IT PAYS TO FEED GOOD DAIRY COWS LIBERALLY

When fed liberally a good dairy cow can use half her feed for milk production. When fed a three-fourths ration she can use only one-third of her feed for producing milk, and when fed a half-ration she needs all her feed to maintain her body. A beef cow, if fed a liberal ration, will turn part of her surplus feed into fat instead of milk. (After Van Norman.)

Influence of feed on yield of product.—Tho the kind and amount of feed do not materially affect the richness of the milk, the amount of milk a cow will yield, and hence the total yield of fat, depends on her feed and care, until her full capacity for milk production is reached. The typical beef cow usually has a very limited capacity for producing milk and yields only sufficient for her calf, even tho her feed be abundant. Any surplus of nutrients is stored in her body as fat. On the other hand, in the well-bred dairy cow the impulse to produce milk is so strong that with abundant and suitable feed and good care she yields much more milk than her calf requires.

Many dairymen make the serious mistake of failing to supply good dairy cows with sufficient feed for the most economical production of milk. As shown in Figure 72, a good dairy cow fed a liberal ration requires about half her feed to maintain her body and uses the other half to make milk. If she receives less feed, the proportion which she can use to produce milk will be decreased. For example, if fed three-fourths of a full ration, she can use only one-third of what she eats to make milk. Should she be fed but half of a full ration, she will still need as much as before to maintain her body and no feed will remain for milk production. Any milk she then yields would be made by robbing her body of nutrients. The true dairy cow thus produces milk most economically when fed a liberal ration, while a cow of beef type or one lacking in dairy temperament, when liberally fed, will store a considerable part of the food nutrients in her body as fat, instead of turning them into milk. A safe rule is to feed such a cow only what she will eat without gaining in weight.

The increase in production due to good feed and care is shown in a striking manner by a trial at the New York (Cornell) Station.[9] A herd of cows poorly fed and cared for by their owner, was taken from a farm to the Station where they were liberally fed for 2 years. Then the cows were returned to their owner and fed by him as before. During the time the cows were at the Station they gave 42 per ct. more milk and 51 per ct. more fat than when with the farmer.

Turning to pasture; temperature; weather.—When cows are turned from winter stables to spring pastures usually both the yield of milk and its richness are slightly increased, but after 2 to 4 weeks the percentage of fat falls to normal. Especially when the grass is soft and lush, cows lose in weight for a short time when first turned to pasture.

The tendency is for cows to give richer milk when the temperature falls and poorer milk as it rises, and so they generally yield slightly poorer milk in summer than in winter. Cows exposed to cold rains shrink in milk flow and may yield milk poor in fat.

Exercise and grooming.—Moderate exercise tends to increase the yield of milk and the richness of all constituents except casein, while too much exercise decreases the yield and injures the quality of the milk. In some trials grooming increased the flow of milk 4 to 8 per ct. while in others where the ungroomed cows were not allowed to become filthy, it brought no increase. Tho grooming may not increase the yield of milk, it does improve its quality by lessening the number of bacteria contained and may improve the health of the animals.

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[9] Wing and Foord, N. Y. (Cornell) Bul. 222.

Milking machines.—Because of the difficulty of securing efficient hand milkers, the use of milking machines is certain to increase. Several types of machines have now been greatly improved and long-continued trials at various stations show that when cows are milked with the best machines by careful operators and with well-adjusted teat cups there is no injurious effect on the yield or quality of the milk, or on the health of the animals. While with most cows the machine does not draw quite all the milk from the udder and it is necessary to strip by hand, considerable time is saved by machine milking. When the machines are properly cleansed and the rubber tubing kept in an antiseptic solution, the sanitary condition of the milk is improved over that ordinarily obtained by hand milking. Owing to the first cost of the machines and the labor involved in their operation and cleansing, various authorities consider machine milking economical under usual conditions only where at least 15 to 30 cows are milked thruout the year.

Regularity and kindness.—For the best results with dairy cows, as with other farm animals, they should be treated with kindness at all times, and regularity in feeding and care should be observed. The highest yielding cows are usually of nervous temperament, and, especially with such animals, excitement usually causes a sharp decrease in yield. Cows being driven should not be hurried and attendants should never strike or otherwise abuse them. Good dairymen now realize the fact brought to public attention by W. D. Hoard of Wisconsin that dairying is based on the maternity of the cow, and treat their animals accordingly. As Haecker writes,[10] "If you so handle the cows that they are fond of you, you have learned one of the most important lessons that lead to profitable dairying. . . . A cow's affection for the calf prompts the desire to give it milk; if you gain her affection she will desire to give you milk."

While milking is usually regarded as a simple task which anyone can do, there may be a great difference in the returns which different milkers get from the same cow. A cow should be milked quietly with the dry hand, and stripped out thoroly, the milker bearing in mind that the last-drawn milk carries about 10 times as much fat as that drawn first.

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[10] Minn. Bul. 130.

Minor points.—Dehorning cows causes a small temporary decrease in milk flow but is repaid a hundred fold in the greater comfort of the herd thereafter. Subjecting cows to the tuberculin test has practically no effect on the yield of milk or fat. Tho milking three times a day may cause a slightly larger flow of milk, it is not profitable except with very heavy milkers and cows on official test.

Flavor, odor, and color.—The flavor and odor of milk and its products are highly important. Due to minute quantities of volatile oils they contain, onions, leeks, turnips, rape, etc., give an objectionable flavor to milk, unless fed immediately after milking so that the volatile oils may escape from the body before the next milking. When cows are first turned to pasture, we at once note a grass flavor in the milk and butter, which soon disappears or which we fail to notice later.

Experiments at the Missouri Station[11] show that the yellow color of butter fat is due to a substance called carotin, so named because it is the same coloring matter found in the carrot. Cows can not make this coloring matter in their body but secure it from feeds which contain it. The yellowness of cream and butter in summer is due to the fact that green feeds are rich in carotin, tho we can not see it because the green chlorophyll masks its color. Bright green hay and yellow roots also contain much carotin, while most concentrates and dry roughages are poor in this coloring matter.

Butter and cream from Guernsey and Jersey cows is yellower than that from other breeds, not because these cows can manufacture carotin, but because they can transfer to their milk a larger part of the carotin in their feed. They also store the yellow carotin in their body fat, in winter transferring some of it to their milk.

III. Feeding for Milk Production

Imitate pasture conditions the year around.—Every dairyman knows that his herd normally reaches maximum production when on luxuriant pasture in late spring or early summer. As Eckles points out,[12] to secure the largest yield during the other months of the year the following summer conditions should be imitated as closely as possible: (1) An abundance of feed; (2) a balanced ration; (3) succulent feed; (4) palatable feed; (5) a moderate temperature; (6) comfortable surroundings; (7) reasonable exercise. Upon the ability of the dairyman to maintain these favorable conditions for his herd thruout the year, depend in large measure his profits.

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[11] Palmer and Eckles, Mo. Res. Buls. 9, 10, 11, 12; also Cir. 74.

[12] Dairy Cattle and Milk Production, p. 257.

The proper concentrate allowance.—A good dairy cow in full flow of milk is expending fully as much energy as a horse at hard work, and hence should not be expected to get all her nourishment from roughages, even if of good quality. How much concentrates to feed is a question of great economic importance to dairymen, for in most cases roughages are the cheap and concentrates the costly part of the ration. The amount of concentrates advisable depends first on the quantity and quality of the roughages furnished; and second, on the productive capacity of the cows. For the most economical production and the largest profit, cows of good dairy temperament should generally receive at least 6 to 8 lbs. of concentrates, in addition to all the good roughage, such as legume hay and corn silage, that they will consume. Exceptional producers can use more concentrates with profit, but, if concentrates are high-priced, cows of only low productive capacity may not pay for any grain in addition to good legume hay and corn silage. The dairyman who persists in giving his cows only such low grade roughages as timothy hay, corn stover, etc., must pay the penalty by feeding them

Fig. 73.—Imitate Summer Conditions the Year Round

The most successful dairymen imitate summer conditions as closely as possible during the rest of the year.

from 10 to 12 lbs. of expensive concentrates daily to secure a reasonable flow of milk.

Cows should be fed individually.—Even when fed liberally, cows of marked dairy temperament rarely lay on flesh when in full flow of milk, provided their ration is well balanced. But cows of ordinary capacity may easily be overfed, in which case they lay on fat instead of increasing their milk production. Since even in well-bred and well-selected herds the different cows vary widely in productive ability, to secure the most profit they must be fed as individuals, instead of giving both high and low producers the same ration. It is not necessary, however, to compute a balanced ration for each animal. All that is needed is to determine what amounts and proportions of roughages and concentrates should be used to make the most economical ration that meets the requirements for the average cows in the herd, after the manner shown in Chapters VII and VIII. For example, the ration on Page 110 meets the average requirements for cows producing 30 lbs. of 3.5 per ct. milk daily. In feeding the herd, each cow should be given all the roughage she will eat, which will usually be about 2 lbs. of dry roughage daily per 100 lbs. live weight, or 1 lb. of dry roughage and 3 lbs. of silage. Then the amount of concentrates for each cow may be determined from one of the following rules:

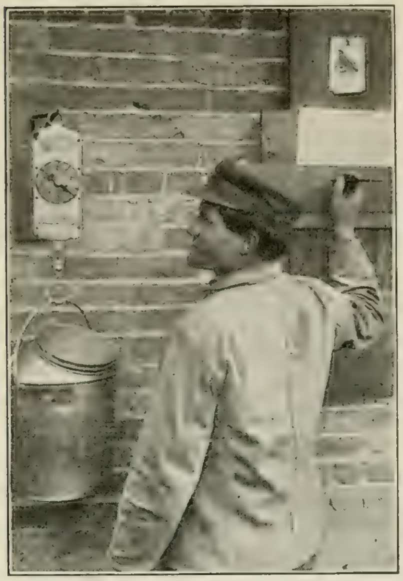

Fig. 74.—The milk scales and the Babcock test enable the dairyman to weed out the unprofitable cows and to feed his good cows individually in proportion to their production. (From Wisconsin Station.)

1. Feed 1 lb. of concentrates per day for each pound of butter fat the cow produces per week, or
2. Feed 1 lb. of concentrates per day for each 3 to 4 lbs. of milk, depending on its richness, or
3. Feed as much as the cow will pay for at the ruling prices for feeds and products, increasing the allowance gradually until she fails to respond by an increase in production which will cover the increase in cost.

The first 2 rules apply only when abundant roughage of good quality is supplied. Heavy producers require a narrower nutritive ratio than ordinary animals, and hence it may be advisable to alter the character of the concentrate mixture for them. It is also wise to feed a more nitrogenous concentrate allowance to cows showing a tendency to fatten, while those losing flesh should receive a larger proportion of the carbonaceous concentrates, such as the farm-grown grains. Since heifers in milk are still growing in addition to giving milk, they should be fed more liberally than mature cows yielding the same amount of milk.

Feeding concentrates on pasture.—The economy of feeding concentrates to cows on good pasture depends on the relative cost of pasturage and concentrates, the price secured for dairy products, and the productive capacity of the cows. While the animal giving only an average quantity of milk may not pay for such addition, the heavy-yielding cow can not long continue her high production without some concentrates, unless the pasture be unusually luxuriant. Eckles[13] concludes that a Jersey giving 20 lbs. or a Holstein yielding 25 lbs. of milk or more daily, should be fed some concentrates on pasture, the amount being left to the business judgment of the dairyman. Feeding a moderate amount of concentrates on pasture is often advisable, even when it does not increase the yield enough to return an immediate profit, for the cows are kept in better condition and will yield more the following months. This is especially true with heifers which are still growing and require liberal feed in order to reach full development.

Supplementing short pasture.—It is of great importance that additional feed be given dairy cows when pastures become parched and scant in midsummer. Otherwise, the milk flow will surely decrease, and even should the pastures improve later, the cows can not be brought back to their normal flow of milk. Corn or sorghum silage usually furnishes the cheapest feed for this purpose, but where this is not available soiling crops should be specially grown.

The ration should be properly balanced.—Because milk is rich in protein and mineral matter, especially lime and phosphorus, the ration of the dairy cow should contain an ample supply of these nutrients. (See Chapter VI.) Fortunately, legume hay is rich in all these constituents, which explains its high value for milk production. As pointed out in Chapter VIII, the amount of protein it will pay to feed depends on the relative prices of protein-rich and carbonaceous feeds. Even when the former are high in price, the protein allowance should not fall far below the minimum shown in

[13] Dairy Cattle and Milk Production, p. 256.

Appendix Table V. In districts where protein-rich feeds are the cheapest, cows have been fed rations as narrow as 1:4 without harm.

Succulent and palatable feed.—Numerous trials have shown the importance of providing succulent feed, either corn silage or roots, for winter feeding to take the place of summer pasture. The value of succulence is due in no small measure to its beneficial laxative effect and to its palatability, which undoubtedly tends to stimulate digestion. Not only should succulent feed be supplied, but the rest of the ration for cows yielding a good flow of milk should be as palatable as possible. Such roughages as timothy hay, straw, and corn stover may be used in limited amount, but should not form the chief roughage. Concentrates not relished when fed alone may be mixed with well-liked feed. The concentrate allowance should be composed of two or more feeds, for a mixture is relished better than a single kind of grain or roughage. It is also well to feed at least two kinds of roughage.

Shelter and comfort.—In winter, the steer, gorged with feed and every day adding to the heat-holding layer of fat just beneath the skin, prefers the yard or open shed to the stable. The dairy cow stands in strong contrast, her system being severely taxed thru the annual drain of maternity and the daily loss of milk. The cow should be comfortably housed in a well-lighted, well-ventilated stable, having a temperature ranging from 40° to 50° F. in winter. To preserve the health of the herd as well as for sanitary reasons, it is advisable to have not less than 4 square feet of window glass for each animal. It is well to disinfect the stable thoroly at least once a year, to check any possible spread of disease. As the dairy cow is a sensitive, nervous animal the wise dairyman will provide comfortable stalls or swinging stanchions, and see that the cows are well bedded.

Water.—Cows in milk require about 100 lbs., or 12.5 gallons, of water per head daily, and heavy yielding cows even more. As cows are creatures of habit, those of ordinary productive capacity will have their needs supplied if once each day they can easily secure all the water they can then drink. High-producing animals should have water at least twice a day. The supply should be of good quality and close by, so the cows will not be forced to travel far.

Opinions differ as to the advisability of warming water for cows in winter. Owing to the heavy rations cows in milk consume, there is a large amount of heat produced in their bodies thru the energy expended in the mastication, digestion, and assimilation of the feed. When comfortably housed, probably little or no nutrients need be burned in the body for warming the water drunk in winter, provided it is no colder than that from a deep well. However, it is advantageous to warm the water for heavy-yielding cows, for unless this is done they may not drink enough to make possible the maximum production of milk. In regions with severe winters cows should be watered indoors when the weather is so bad that it is not desirable to turn them out for exercise.

Salt.—We have already seen in Chapter IV that dairy cows require salt to thrive. An allowance of 0.75 ounce daily per 1,000 lbs. live weight, with 0.6 ounce in addition for each 20 lbs. of milk is generally sufficient.[14] The salt may be regularly mixed with the feed, or the cows may be allowed free access to it.

Preparation of feed.—Since the cow giving a large flow of milk is working hard, her grain should be ground or crushed if not otherwise easy of mastication and digestion. Corn and oats should generally, and wheat, rye, barley, kafir, and milo always, be ground or crushed, and roots should be sliced or pulped. There is no advantage in cooking or soaking ordinary feeds.

Frequency and order of feeding.—On account of the large capacity of the cow's paunch and the considerable time needed for rumination, the common practice of feeding cows twice daily, with possibly a little roughage at noon, is a reasonable one. In the roomy paunch hay and grain, eaten separately, are thoroly mixed by the churning action and gradually softened in the warm, abundant liquid the paunch contains. This true, the particular order of feeding roughages and concentrates is not important, tho the same order should be followed from day to day and the cows should be fed at regular intervals. Hay and other dry forage is usually not fed till after milking, because they fill the air with dust. Silage, turnips, cabbage, or other feeds with a marked odor should be given only after milking.

Cows need a rest.—Dairymen agree that it is best to give the dairy cow a rest by drying her off 6 to 8 weeks before freshening, for she will then produce more milk annually than if milked continuously. To avoid injury to the udder she should be dried off gradually. She should also be in good condition at calving, for this insures a good flow of milk and lessens the trouble in calving. Only sufficient concentrates should be fed to put her in proper flesh, and if she has been heavily fed with rich concentrates while giving milk, a helpful change may now be made to a ration which will rest and cool the digestive tract. Just previous to calving the feed should be slightly laxative, tho if on pasture no especial attention need be given to this point. For cows that freshen while housed nothing is better than legume

[14] Babcock and Carlyle, Wis. Rpt. 1905.

hay and silage, with a couple of pounds of concentrates added, if necessary.

Calving time.—The gestation period of the cow is from 280 to 285 days. At calving time she should be kept in a clean, comfortable, well-bedded box stall unless on pasture, and should not be molested unless assistance is required. In winter her drinking water should be lukewarm for 2 or 3 days after calving, and she should be protected from cold drafts, for her vitality is then low. The feed for the first few days should be limited in amount and of cooling, laxative nature. Besides legume hay and silage, she may be given such feeds as bran, often fed as a mash, oats, and linseed meal. High-producing cows should be watched closely for signs of milk-fever, and the air treatment, the great boon to dairymen, used if necessary. The yearly production of the cow depends in a considerable measure on the feed she receives during the first month after calving. The concentrate allowance, small at first, should be increased gradually, at the rate of a half-pound every other day until the full allowance is reached, for heavy feeding immediately after calving may lead to digestive disturbances. If the udder is swollen and hard, even more care should be used in getting the cow to the full ration.

By having cows freshen in the fall a larger annual yield of milk is possible, for they give a good flow during the winter and are stimulated to high production again when turned to pasture in spring. Spring-fresh cows yield most of their milk when dairy products are low in price and when the dairyman is busiest with his crops. When cows freshen in the fall more time can be given to the raising of the calves, and there will be less trouble from scours than in summer. Fall-dropped calves are large enough by spring to make good use of pasture and are better able to stand the hot weather.

IV. The Cost of Milk Production

Annual feed requirement.—The following table shows the amount and cost of feed consumed annually by dairy cows and the returns in milk and fat, as shown by trials at 10 widely separated American stations.

At the Massachusetts Station the cows were fed soilage in the summer, only the dry cows being turned to pasture. In New Jersey they were likewise maintained in summer almost wholly on soilage and silage. At the other stations the pasture period ranged from 131 days in Minnesota to 191 in Missouri. The great value of alfalfa hay in reducing the amount of concentrates fed and the cost of keep is shown by the Utah and Montana reports. The prices of feed have increased greatly in many instances since these results were reported, but from the data in the table one can readily estimate the yearly cost of feed at local market prices.

Feed requirement of the dairy cow as found by ten stations

Stations	No. of years	Feed eaten				Av. cost of feed per cow	Returns	
		Pasture	Concentrates	Silage, roots, soilage	Hay		Milk	Fat
		Days	Lbs.	Lbs.	Lbs.	Dols.	Lbs.	Lbs.
Massachusetts [1]	6	38	2,149	4,938	5,105	90.04	6,036	306
Connecticut [2]	5	152	2,029	8,694	1,830	53.46	5,498	279
New Jersey [3]	6	168*	2,624	16,753	1,825	44.68	6,165	277
Michigan [4]	1	139	2,774	3,638	3,986	35.96	7,009	260
Wisconsin [5]	3	180	1,914	9,448	1,200	37.68	7,061	299
Wisconsin [6]	4	150*	2,010	8,318	1,490	48.82	8,036	344
Minnesota [7]	1	131	3,435	5,306	2,029	37.82	6,408	301
Missouri [8]	1	191	3,027	....	3,480	35.30	5,927	248
Utah [9]	5	153	1,305	....	4,518	21.43	5,601	237
Montana [10]	2	150	1,169	.....	6,468	32.45	5,993	250
Nebraska [11]	2	187	1,979	3,692	2,347	31.61	8,783	339

[1] Bul. 145. [2] Bul. 29. [3] Rpts. 1897–1904. [4] Bul. 166. [5] Rpts. 1905–7. [6] Buls. 167, 187, 217. [7] Bul. 35. [8] Bul. 26. [9] Bul. 68. [10] Rpt. 1905. [11] Bul. 101.

* Pasture limited in amount.

Cost of milk production.—The cost of feed is by far the largest single item in the cost of producing milk, making up from one-half to two-thirds the total gross cost. Next in importance is the cost of man and also horse labor in milking and feeding the cows, cleaning the stables, handling and hauling milk, etc. This will make up at least one-fifth to one-fourth the total gross cost. In addition to cost of feed and labor, the following must be included to ascertain the actual cost of producing milk: (1) depreciation, interest, and taxes on the cow herself; (2) depreciation, interest, and taxes on buildings; (3) depreciation and interest on barn tools and dairy implements; (4) cost of perishable tools and supplies, including bedding, ice, salt, brushes, record sheets, etc.; (5) proportionate cost of pure-bred sire; (6) miscellaneous expenses, including mortality risk and veterinary services. Under present conditions, the gross cost of all items except feed will be $40 to $75 or over a year, varying considerably for the different sections of the country, depending on the price of labor, the shelter required, etc. From the gross cost should be deducted the birth value of the calf and the value of the manure produced.

Several formulas have been devised in an attempt to estimate the cost of producing milk with feeds at various prices. Pearson of the Illinois Station [15] has worked out the following formula, in which all costs in milk production are reduced to terms of the prices for feed and man labor.

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[15] Ill. Bul. 216.

The average net cost thruout the year of producing 100 lbs. of milk is equal to the cost of the following at local prices: Grain, 44 lbs.; silage, 188 lbs.; hay, 50 lbs.; other roughage, 39 lbs.; man labor, 2.42 hrs.

As it costs considerably more to produce milk in winter than in summer when the cows are on pasture, in order to secure a steady supply of milk for city consumption, the price paid farmers must be higher in winter than in summer. The average monthly prices paid to farmers supplying milk to Chicago from 1907 to 1916 have been the following percentages of the average annual price: January, 119.0 per ct.; February, 114.3 per ct.; March, 106.5 per ct.; April, 94.2 per ct.; May, 73.2 per ct.; June, 70.6 per ct.; July, 83.7 per ct.; August, 94.2 per ct.; September, 96.7 per ct.; October 109.2 per ct.; November, 118.3 per ct.; December, 120.3 per ct. Pearson believes that these monthly prices correspond roughly with the monthly variations in the cost of producing milk in this section.

QUESTIONS

1. Compare the economy with which the cow and the steer produce human food.
2. What is meant by dairy type and beef type?
3. How do good and poor producers compare in economy of production?
4. How would you build up a herd of high-producing cows?
5. Discuss the keeping of records of production and the work of cow testing associations.
6. What is the common range in composition of milk?
7. What is the average percentage of total solids and fat in Jersey, Guernsey, Ayrshire, and Holstein milk?
8. Discuss the influence of individuality, portion of milk drawn, period between milkings, age of cow, advancing lactation, and condition at calving on the composition and yield of milk.
9. What influence does the feed have: (a) on the richness of milk; (b) on the amount of milk produced?
10. How do turning to pasture, temperature, weather, exercise, grooming, milking machines, and regularity and kindness affect milk production?
11. What causes the yellow color of butter fat?
12. Name seven pasture conditions which should be imitated during the rest of the year.
13. How much concentrates should be fed to dairy cows: (a) in winter; (b) on pasture? Would you feed the same amount to all the cows in the herd?
14. Discuss the importance of properly balanced rations, succulent and palatable feed, shelter and comfort, water, salt, preparation of feed, and frequency and order of feeding.
15. How should cows be fed and cared for before calving and at calving time?
16. Find the actual amounts and cost of feed given dairy cows in a good herd in your vicinity and compare with the figures in this chapter.

CHAPTER XXI

FEEDS FOR THE DAIRY COW

I. CARBONACEOUS CONCENTRATES

With the high prices now ruling for feed and labor, on many farms, even where good dairy cows are kept, milk is being produced at little or no profit to the owner. Yet, by a wise selection of feeds other dairymen secure goodly profits from cows no better. This shows emphatically that the feeding of the herd should be given most careful study, and the system of farming so planned that a ration both well balanced in chemical nutrients and otherwise satisfactory may be provided at minimum expense.

Indian corn.—Thruout the corn belt Indian corn, a grain highly relished by the cow, is usually the cheapest carbonaceous concentrate available. Owing to its wide nutritive ratio, corn should be used as the sole concentrate only when leguminous roughages supply the lacking protein, and even then more variety in the ration is advisable. The poor results secured when corn is not properly balanced by protein-rich feeds are shown in the following table. This gives the results of a trial at the Illinois Station[1] in which one lot of cows was fed a well-balanced ration, in which gluten feed and clover hay furnished the necessary protein, while a second lot was fed corn as the only concentrate, with corn silage, timothy hay, and a small amount of clover hay.

Corn requires supplement for feeding dairy cows

Average ration		Nutritive ratio	Average daily yield	
			Milk Lbs.	Fat Lbs.
Lot I, balanced ration				
Ground corn, 3.3 lbs. Gluten feed, 4.7 lbs.	Clover hay, 8 lbs. Corn silage, 30 lbs.	1: 6	30.1	0.96
Lot II, unbalanced ration				
Ground corn, 8 lbs.	Timothy hay, 5 lbs. Clover hay, 3 lbs. Corn silage, 30 lbs.	1:11	20.5	0.69

During the trial the cows in Lot I produced 47 per ct. more milk and 39 per ct. more fat than those in Lot II, fed the same weight

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[1] Fraser and Hayden, Ill. Bul. 159.

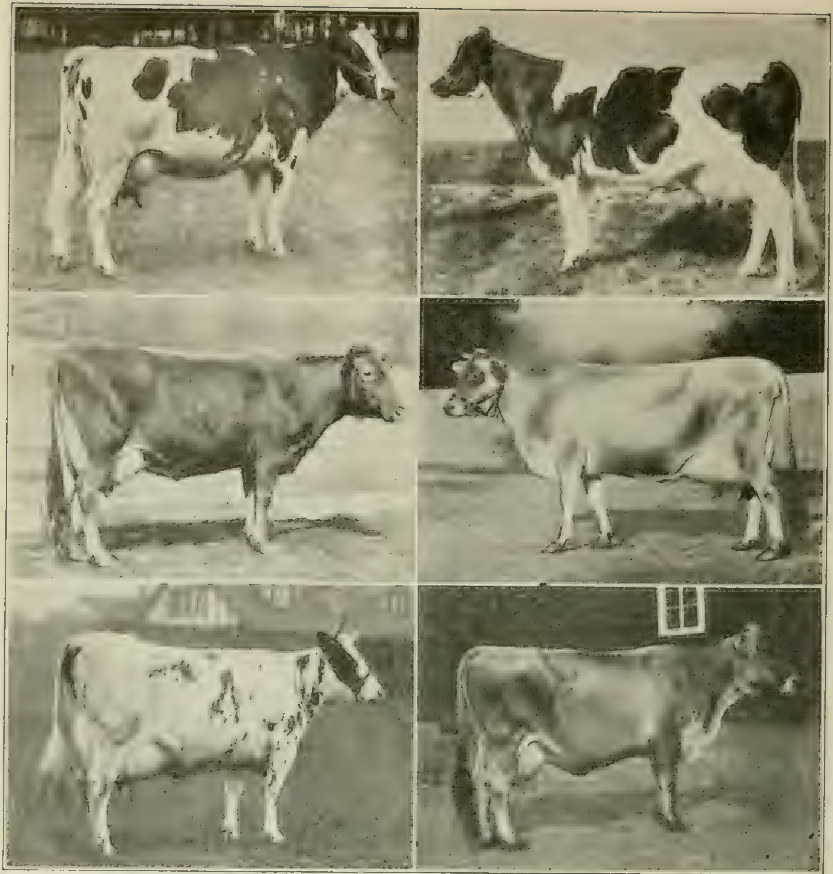

Fig. 75.—Champion Cows of the Dairy Breeds, 1917

Upper, left.—Holstein cow, Duchess Skylark Ormsby. Record at 5 years of age, 27,761.7 lbs. milk, containing 1205.09 lbs. butter fat. (World's record for butter fat production.) Owned by John B. Irwin, Minneapolis, Minn.

Upper, right.—Holstein cow, Tilly Alcartra. Record at 5 years of age, 30,452.6 lbs. milk, containing 951.20 lbs. butter fat. (World's record for milk production.) Owned by A. W. Morris and Sons, Woodland, Cal.

Middle, left.—Guernsey cow, Murne Cowan. Record at 8 years of age, 24,008.0 lbs. milk, containing 1,098.18 lbs. butter fat. Owned by O. C. Barber, Akron, Ohio.

Middle, right.—Jersey cow, Sophie 19th. of Hood Farm. Record at 7 years of age, 17,557.8 lbs. milk, containing 999.14 lbs. butter fat. Owned by C. I. Hood, Lowell, Mass.

Lower, left.—Ayrshire cow, Lily of Willowmoor. Record, 22,596 lbs. of milk, containing 955.56 lbs. butter fat. Owned by J. W. Clise, Redmond, Wash.

Lower, right.—Brown Swiss cow, College Bravura. Record, 19,460.6 lbs. milk, containing 798.16 lbs. butter fat. Owned by Michigan Agr. College. (Photo from *Hoard's Dairyman.*)

of concentrates and roughages, but in an unbalanced ration. This shows the folly of expecting profitable production from such unbalanced combinations of feed, even tho they may be palatable.

Corn is commonly ground for dairy cows, but sometimes ear or shock corn is fed. When other bulky concentrates are not furnished it may be advisable to feed corn in the form of corn-and-cob-meal.

Hominy feed.—This by-product, quite similar to corn in composition, compares favorably with it in feeding value. Like corn, it should be supplemented by feeds rich in protein.

Oats.—This grain, which supplies somewhat more protein than does corn or wheat, is an excellent feed for the dairy cow, but, owing to their high price, it is usually not economical to use any large amount of oats. The various concentrate by-products are generally cheaper sources of crude protein, while corn furnishes carbohydrates at less expense.

Barley, wheat, rye, emmer.—*Barley* is quite widely fed to dairy cows in Europe, and has a reputation for producing milk and butter of excellent quality. Recent trials at the Wisconsin station show that ground barley is fully equal to ground corn. *Wheat*, which is usually too high priced for feeding except when of poor quality, has about the same value for cows as corn. Large allowances of *rye* produce a hard, dry butter, but 2 to 3 lbs. per head daily mixed with other feeds has given good results. *Emmer* is about 13 per ct. less valuable than corn or barley for dairy cows. All these small grains should be ground, or, preferably, rolled.

Kafir, milo, and sorghum.—These grains are of great importance to dairymen in the semi-arid Southwest, being the cheapest concentrates available. Meal from the sweet sorghums is only 10 to 15 per ct. less valuable than corn, and kafir and milo probably approach corn even more closely in value.

Dried beet pulp.—On account of its slightly laxative and cooling effect, this bulky, carbonaceous concentrate has become popular with dairymen, especially for cows on forced test. It is about equal to corn in value. Where silage is not available, dried beet pulp, moistened before feeding, as it should always be when fed in large amount, is a satisfactory, tho usually an expensive, substitute.

II. Protein-Rich Concentrates

Wheat bran.—This palatable, bulky concentrate is one of the most esteemed feeds for the dairy cow, since it is fairly high in crude protein, rich in phosphorus, and has a beneficial laxative effect on the digestive tract. Owing to its popularity, bran is often high in price, considering the amount of crude protein it furnishes. Other by-products, such as gluten feed, dried brewers' grains, and cottonseed meal, which are richer in digestible crude protein, are therefore usually more economical supplements for rations low in protein. Hence, it is often best to feed bran only in limited amount for its beneficial effect on the health of the animals, rather than attempt to balance the ration with bran alone. This concentrate is especially valuable for cows just before and after calving, for those on official test, and for young, growing animals.

Wheat middlings or shorts; wheat mixed feed.—Tho higher in digestible crude protein than wheat bran, middlings or shorts are less palatable and are heavy, rather than bulky feeds. They should hence be fed to dairy cows only in limited amounts, mixed with other concentrates. Due to its higher content of digestible crude protein and carbohydrates, a good grade of wheat mixed feed is worth about 10 per ct. more than wheat bran.

Corn gluten feed; gluten meal; germ oil meal.—*Gluten feed*, which carries about twice as much digestible crude protein as wheat bran, is a valuable concentrate for the dairy cow. It contains only about 70 per ct. as much digestible crude protein as linseed meal, but furnishes slightly more total digestible nutrients. In a trial at the Iowa Station [2] gluten feed was equal to linseed meal when forming one-third of the concentrates, with alfalfa hay and corn silage for roughage. *Gluten meal* is used much less for dairy cows than gluten feed, but is a satisfactory concentrate. It is much heavier, due to the absence of the corn bran, and contains as much crude protein as linseed meal. *Germ oil meal* and wheat bran, mixed in equal parts, proved superior to a mixture of 1 part cottonseed meal, 1 part linseed meal, and 2 parts wheat bran in a trial at the Vermont Station.[3]

Dried brewers' grains.—Before national prohibition, this bulky concentrate was widely fed to dairy cows. Considerable amounts are still produced as a by-product in the manufacture of near beer, etc. It is superior to wheat bran, for it contains over 70 per ct. more digestible crude protein and slightly more total digestible nutrients.

Malt sprouts.—Tho not especially palatable, malt sprouts may be successfully fed to dairy cows when mixed with other feeds, if not over 3 to 3.5 lbs. are fed per head daily.[4] As malt sprouts swell greatly on absorbing water they should be soaked before feeding to avoid digestive disturbances, when over 2 lbs. daily are fed.

Cottonseed meal.—Experience has shown that cottonseed meal may be fed to dairy cows in properly balanced rations for years with no

[2] Information to the authors. [3] Hills, Vt. Rept. 1901. [4] Lindsey, Mass. Bul. 94.

ill effect. This is most fortunate, since this highly nitrogenous feed is usually the cheapest source of protein in the South and often likewise in the North. Owing to its richness in protein, cottonseed meal is even more valuable than linseed meal for balancing rations low in this nutrient, and is worth considerably more than gluten feed or dried distillers' grains. Since cottonseed meal is constipating it should be fed with laxative concentrates, such as linseed meal or wheat bran, or with succulent feed, such as silage or roots. The milk of cows heavily fed on cottonseed meal yields a hard, tallowy butter, light in color and poor in flavor. If a moderate allowance is fed in a properly balanced ration, the quality is not injured and may even be improved if the other feeds tend to produce a soft butter. Some authorities recommend feeding no more than 2 to 3 lbs. of cottonseed meal per head daily. However, when this highly nitrogenous, heavy feed is mixed with others which are bulky and lower in protein and the cows are fed silage or other succulence, as much as 4 lbs. of the meal has been fed daily to large cows with good results. At the North Carolina Station [5] a mixture of equal parts cottonseed meal, dried beet pulp, and dried distillers' grains was highly satisfactory when fed with corn silage. A mixture of cottonseed meal, corn meal, and wheat bran also gave good results.

Linseed meal.—This slightly laxative, cooling, protein-rich concentrate is one of the best dairy feeds, but its popularity usually makes it more expensive than some of the other protein-rich feeds which are usually available. Nevertheless, 1 to 2 lbs. per head daily is often advisable on account of its tonic and laxative effect, especially with cows out of condition and those soon to freshen. Linseed meal tends to produce a soft butter and therefore may be advantageously added to rations that produce a tallowy product.

Dried distillers' grains.—Previous to national prohibition, dried distillers' grains were extensively employed for feeding dairy cows. Corn distillers' grains are slightly more valuable than gluten feed, but furnish less protein than cottonseed meal or linseed meal. The rye distillers' grains are of lower value than those chiefly from corn. At the Kentucky Station [6] it was found that some cows would not eat large allowances of dried distillers' grains until they became accustomed to the slightly sour smell and taste.

Soybeans; soybean meal or cake.—Ground *soybeans* have proved slightly superior to cottonseed meal when not over 2 to 3.4 lbs. were fed mixed with other concentrates. Too large an allowance of soybeans makes soft butter. This fault can be corrected by feeding them with cottonseed meal.

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[5] Proc. Amer. Soc. Anim. Prod. 1914.

[6] Hooper, Ky. Bul. 171.

Soybean meal or *cake,* from which the fat has been extracted, does not make soft butter, and is slightly more valuable than cottonseed meal.

Cocoanut meal.—When no more than 3 to 4 lbs. per head daily is fed, cocoanut meal produces a firm butter of excellent quality. More may make too hard a butter. Cocoanut meal is about equal to gluten feed for dairy cows.

III. Hay from the Legumes

Legume hay for the dairy cow.—Over much of this country the Indian-corn plant provides the cheapest, most abundant, and most palatable carbohydrates the farmer can produce, but it falls short in furnishing protein, so vital in milk production. Happily, wherever corn flourishes at least one of the legumes—alfalfa, clover, cowpeas, vetch, etc.—can be grown to meet this deficiency. High in crude protein and mineral matter, especially lime, the legume hays aid greatly in reducing the amount of expensive protein-rich concentrates needed to provide a properly balanced ration for dairy cows. The following articles show that when plenty of good legume hay and silage from nearly matured and well-eared corn is supplied, only half as much concentrates need be fed as when only carbonaceous roughages are used.

Alfalfa hay.—Good alfalfa hay heads the list of roughages suitable for the dairy cow, on account of its high content of protein and its palatability. Leafy, early-cut alfalfa hay is the best for dairy cattle. The value of this hay in balancing rations otherwise low in protein is shown in a trial at the Ohio Station [7] in which 2 lots each of 6 cows were fed the rations shown below for 56 days:

Alfalfa hay as source of protein for dairy cows

Average ration		Average daily yield		
		Milk Lbs.	Fat Lbs.	Nutritive ratio
Lot I				
Alfalfa hay, 11.6 lbs. Corn silage, 27.8 lbs.	Corn meal, 5.9 lbs.	22.0	0.87	1:7.0
Lot II				
Corn stover, 5.6 lbs. Corn silage, 29.3 lbs.	Cottonseed meal, 3.1 lbs. Wheat bran, 3.1 lbs. Corn meal, 3.1 lbs.	20.5	0.90	1:5.7

The ration fed Lot I—alfalfa hay, corn silage, and corn meal—would undoubtedly have been improved had a greater variety of concentrates been fed, yet with alfalfa hay as the sole supplement, a well-balanced ration was provided which produced substantially as good results as that fed Lot II, in which wheat bran and cottonseed meal furnished most of the protein. While Lot II was fed 9.3 lbs. of rich concentrates, Lot I received only 5.9 lbs. of corn meal.

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[7] Caldwell, Ohio Bul. 267.

Similar results have been secured in other trials where alfalfa hay has replaced half or even somewhat more of the concentrates usually fed.

Substituting alfalfa hay for all the concentrates.—In a still more drastic trial of the value of alfalfa hay for milk production at the New Jersey Station [8] all the concentrates for one lot of cows were replaced by alfalfa hay, as shown in the table:

Replacing all the concentrate allowance with alfalfa hay

Average ration		Average daily yield Milk	Fat	Feed cost per 100 lbs. milk *
		Lbs.	Lbs.	Cents
Ration I				
Corn stover, 6.8 lbs.	Distillers' grains, 4.6 lbs.			
Corn silage, 40.0 lbs.	Wheat bran, 4.2 lbs.			
	Cottonseed meal, 0.5 lb.	24.6	1.07	83.7
Ration II				
Alfalfa hay, 17.5 lbs.				
Corn silage, 35.0 lbs.	No concentrates	20.4	0.88	94.4

* Cost of feeds per ton: alfalfa hay, $16; corn silage, $3; corn stover, $4; distillers' grains, $30; wheat bran, $24; and cottonseed meal, $34.

In this trial when the cows were fed Ration II, containing a heavy allowance of alfalfa hay with no concentrates, the yield of milk was 17 per ct. and of fat 18 per ct. less than when Ration I, containing over 9 lbs. of purchased protein-rich concentrates, was fed. With feeds at the prices stated, milk was produced more cheaply on Ration I. The relative economy of such rations obviously depends on the price of alfalfa hay compared with concentrates.

The preceding trials show that alfalfa hay can be substituted for a large part of the concentrates in the ration of the dairy cow without materially reducing the yield of milk or fat. However, when all the concentrates are so replaced the yield of cows of good productive capacity is markedly decreased. This is reasonable, for, tho standing at the head of all roughages, alfalfa hay is nevertheless a roughage and not a concentrate. It contains about 3 times as much fiber as wheat bran and furnishes but 70 per ct. as much net energy. Bearing in mind the productive capacity of his cows and the price of legume hay compared with concentrates, each dairyman must decide for himself to what extent it is economical to substitute legume hay for concentrates.

[8] Billings, N. J. Bul. 204.

In some sections of the West, owing to the cheapness of alfalfa hay, dairy cows are given this feed alone, possibly with green alfalfa soilage or pasturage in addition during the summer. Complaints are made that this unbalanced ration, which is too high in protein and too low in net nutrients, does not always maintain the animals in as good health as where concentrates or even roughages lower in protein are added.

Alfalfa meal.—In view of the palatability of alfalfa hay to the dairy cow and its thoro mastication during rumination, alfalfa meal is ordinarily not economical when good alfalfa hay is available, for the fine grinding does not increase its value.

Fig. 76.—Dairy Cows Utilizing Land Unsuited for Tillage

One of the great advantages of live stock is that they can graze upon land unsuited for tillage. (From *Kimball's Dairy Farmer.*)

Clover hay.—Hay from the clovers, cut while yet in bloom, is one of the best roughages for dairy cows. Tho somewhat lower than alfalfa hay in protein, red clover hay furnishes a slightly larger amount of net energy. By the use of clover hay—red, alsike, or crimson—the amount of concentrates needed to supply a well-balanced ration can be reduced just as when alfalfa hay is used. For example, in a trial at the New Jersey Station[9] cows fed 16.4 lbs. of crimson clover hay and 30 lbs. of corn silage per head daily with no concentrates gave 15 per ct. less milk than when fed 6 lbs. of wheat bran, 5 lbs. dried brewers' grains, 30 lbs. corn silage and 5 lbs. mixed hay. Replacing the concentrates by crimson clover hay, however, effected a saving of over 18 cents in the feed cost of producing 100 lbs. of milk.

Hay from other legumes.—In the South, the *cowpea,* which thrives on all types of soil, is of great importance to the dairy industry, as it furnishes palatable hay rich in protein. This may be used just like alfalfa or clover hay in replacing protein-rich concentrates. In a trial at the New Jersey Station[10] a ration of 17 lbs. cowpea hay and 36 lbs. corn silage produced but 2 lbs. less milk and 0.13 lb. less fat per cow daily than a ration of 9 lbs. of protein-rich concentrates, 36 lbs. corn silage, and 5 lbs. corn stover. Milk was produced cheapest on the home-grown ration. Where they thrive *soybeans, vetch,* and *field peas* all furnish excellent protein-rich hay for dairy cows.

IV. Carbonaceous Roughages

Corn fodder.—Tho inferior to corn silage, good corn fodder, especially that from thickly planted corn, is relished by cows and is a satisfactory substitute for hay from the grasses. In a trial at the Pennsylvania Station[11] corn fodder proved practically equal to timothy hay, and twice as much can ordinarily be produced on a given area. Rather than being fed as the sole roughage, it should preferably be used with legume hay.

Corn stover.—In trials at the Wisconsin Station[12] 1 ton of mixed clover and timothy hay proved equal to 3 tons of uncut corn stover, and clear clover hay was somewhat more valuable. Thirty-four per ct. of the coarse, uncut stover was left uneaten. Had the material been cut, the cows would have wasted somewhat less and the stover would then have had a higher value. These trials show the heavy losses in feeding dry corn forage, while if the forage were ensiled, practically all would be consumed.

Timothy hay.—While timothy hay is a standard roughage for the horse, it is unsatisfactory for the dairy cow. It lacks protein, is not very palatable to cows, and has a constipating effect quite opposite to the beneficial action of legume hay. The value of mixed clover and timothy hay for cows will depend on the proportion of clover present. To show the poor results secured when timothy hay is fed with other feeds likewise low in protein, the Illinois Station[13] conducted a trial on a dairy farm with 2 lots, each of 8 cows. They were fed 10 lbs. of either timothy or alfalfa hay per head daily with 10 lbs. corn stover and 12.5 lbs. of a concentrate mixture of 2.5 parts of corn meal and 1 part of wheat bran. When fed the alfalfa hay ration, which had a nutritive ratio of 1:6.6, the cows produced over one-sixth more milk than on the unbalanced timothy hay ration, the nutritive ratio of which was 1:10.2. The timothy-fed cows lost in weight and were in poor condition generally. The production would have been even lower had not a small amount of bran been fed. This trial shows clearly that when hay from any of the grasses must be fed it should be supplemented by concentrates high in protein.

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[9] Lane, N. J. Bul. 161.

[10] Lane, N. J., Bul. 174.

[11] Hunt and Caldwell, Penn. Rpt. 1892.

[12] The senior author, Wis. Rpt. 1884.

Cottonseed hulls.—Cottonseed hulls contain a fair amount of digestible carbohydrates, but are very low in crude protein and are rather unpalatable to cows. Southern dairymen can supply roughage for their herds more cheaply in the form of corn silage than by buying cottonseed hulls. Silage is also more palatable and stimulates a larger flow of milk. Tho good corn stover is worth fully as much as cottonseed hulls, southern dairymen often leave the corn stalks in the field and purchase the hulls for roughage.

Other carbonaceous roughages.—Brome hay and upland prairie hay equal timothy in value. Hay from other grasses and from the cereals is likewise used for feeding dairy cows. In the plains states fodder and stover from the sorghums are common feeds, resembling the forage from corn in feeding value. Straw is inferior to corn stover and is usually not fed in any large amount to dairy cows in this country. A limited amount of good bright oat straw, however, often may be fed with economy even to dairy cows. The cows may be allowed to pick over the straw and the remainder used for bedding.

V. SUCCULENT FEEDS

Corn silage.—The importance of succulent feeds for milk production has been pointed out in the preceding chapter. Thruout the chief dairy sections of the United States, corn silage furnishes the cheapest form of succulence. Due largely to the fact that the silage made during earlier years was frequently of poor quality and fed in a careless manner, a widespread belief existed that silage injured the flavor of the milk. For many years the largest milk condensing company in the country prohibited the use of silage by its patrons. Experience has now abundantly demonstrated that when good silage is fed under proper conditions the quality of the milk is improved, rather than injured. Like other feeds, silage may be abused. Only that which is well made should be used, and this should be fed directly after milking and be eaten up clean at each feeding, none being left scattered on the floor of the stable. The air of the stable should be kept pure and wholesome by proper ventilation. Under such conditions no one need fear ill effects from feeding silage to dairy cows, for when so fed even the milk condensing factories no longer object to its use. The daily allowance of silage usually ranges from 20 to 40 lbs. per 1,000 lbs. live weight. A common rule is to feed cows 3 lbs. of silage and 1 lb. of dry roughage per 100 lbs. live weight.

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[13] Fraser and Hayden, Ill. Bul. 146.

In 9 trials at various stations in which corn silage was compared with corn fodder, on the average 7.4 lbs. more milk was produced from each 100 lbs. of dry matter in the rations containing silage than in those containing fodder corn. Since silage is no more digestible than dry fodder, its superiority must be largely due to the fact that while good-quality silage is eaten with little or no waste, a considerable part of the corn fodder is usually left uneaten. Another reason is that cows getting the succulent, palatable silage consume a heavier ration than those fed the dry fodder and hence have a larger amount of nutrients available for milk production after the maintenance requirements of the body have been met.

Trials at the Maine and Vermont Stations[14] show that 280 to 350 lbs. of corn silage is worth rather more than 100 lbs. of mixed hay. At the Utah Station[15] 310 to 320 lbs. of corn silage replaced 100 lbs. of alfalfa hay when fed in rations containing ample protein.

Silage other than corn.—Silage from the grain sorghums and the sweet sorghums, cut at the proper stage of maturity, is but little inferior to that from corn. These crops are of great importance to the dairymen of the southwestern states. Clover and alfalfa are sometimes ensiled, tho there is far less certainty of securing good silage from them than from corn or the sorghums. Such combinations as field peas with oats, soybeans or cowpeas with corn or the sorghums, and vetch with oats, wheat, or barley, make satisfactory silage, rich in protein.

Roots.—Tho roots are excellent for dairy cows, they are little used in this country because corn silage furnishes much cheaper succulence. Tho nearly 90 per ct. of the dry matter in roots is digestible and only 66 per ct. of that in corn silage, in actual feeding trials the dry matter of silage has proven fully as valuable as that in roots. Since corn silage contains more dry matter than roots, it is worth considerably more per ton. Sugar beets and mangels are the roots most commonly fed to dairy cows, the former having the higher value per ton on account of their less watery nature. Rutabagas and turnips should be fed immediately after milking to avoid tainting the milk.

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[14] Jordan, Maine Rpt. 1889; Hills, Vt. Rpt. 1901.

[15] Carroll, information to the authors.

Many breeders esteem roots highly for cows which are being forced to the utmost production on official tests. They have a "cooling" effect on the digestive organs, helping to prevent digestive trouble when cows are fed all the rich concentrates they will consume. In addition, adding roots even to a palatable ration containing good corn silage seems to slightly increase the yield of milk and fat. This small increase may make such feeding of roots advantageous for breeders seeking high records. The practice will rarely be economical for dairymen in general, for the Michigan Station [16] has shown that the additional milk produced thereby will not pay for the roots fed.

FIG. 77.—FEEDING GREEN CORN TO KEEP UP THE MILK FLOW

If additional feed is not supplied when pastures become parched in midsummer, the milk flow will surely decrease and it will not be possible to bring the cows back to their normal yield even should the pastures improve later.

Potatoes.—A heavy allowance of potatoes produces milk of poor flavor. They may be used with success, however, when not over about 33 lbs. of cooked potatoes are fed per head daily, or somewhat less of the raw tubers.

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[16] Shaw and Norton, Mich. Bul. 240.

Wet beet pulp.—Wet beet pulp is liked by cows and produces milk of good quality when not fed in excess. In a trial at the New York (Cornell) Station,[17] good results were secured when cows were fed 50 to 100 lbs. of wet beet pulp per head daily with 8 lbs. of grain and 6 to 12 lbs. of hay. As it contains only 9 to 10 per ct. dry matter, wet beet pulp is worth about one-third as much as corn silage per ton.

Soilage.—Trials at the Wisconsin [18] and Nebraska [19] Stations show that corn silage furnishes just as satisfactory and much cheaper feed to supplement short summer pasture than does a succession of soiling crops, such as red clover, peas and oats, sweet corn, and field corn. Where too few cows are kept to consume the silage fast enough to prevent its spoiling or where silage is not available for any other reason, the wise dairyman will provide a well-planned succession of soiling crops to keep up the milk flow when pastures are scant.

QUESTIONS

1. With what other feeds should corn or the other cereals be combined for dairy cows?
2. How does the value of hominy feed, oats, barley, wheat, rye, emmer, kafir, and dried beet pulp compare with that of corn?
3. Compare the value for cows of wheat bran, gluten feed, cottonseed meal, linseed meal, and dried distillers' grains.
4. Name five other protein-rich concentrates used for dairy cows and discuss their value.
5. Show by giving the results of feeding trials how legume hay may be substituted for expensive concentrates.
6. What is the value of corn fodder, corn stover, timothy hay, and cottonseed hulls for cows?
7. Discuss the value of corn silage for milk production.
8. What other crops furnish satisfactory silage for dairy cows?
9. Under what conditions should roots be fed to cows?
10. Compare soilage and silage for summer feeding.

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[17] Wing and Anderson, N. Y. (Cornell) Bul. 183.
[18] Woll, Humphrey and Oosterhuis, Wis. Bul. 235.
[19] Frandsen, Hoard's Dairyman, 47, 1914, p. 403.

CHAPTER XXII

RAISING DAIRY CATTLE

I. The Skim-milk Calf

The profits of dairying depend largely on carefully rearing the heifer calves from the best cows in the herd. Starting with common cows, in a few years one may easily and economically build up a high-producing herd by using good pure-bred sires and steadily replacing the inferior cows with home-raised heifers of greater productive capacity. On the other hand, the dairyman who replenishes his herd by purchases must pay high prices for cows and heifers, which, tho of good appearance, are too often poor producers. Another important reason for raising the heifers is that under this system it is far easier to keep the herd free from such diseases as tuberculosis and contagious abortion. The prudent dairyman accordingly first sees that the calves are well-bred and then so feeds and cares for them that they are not stunted, but reach full development.

Raising calves on skim milk.—The fat of milk is so valuable that but few dairy calves are now raised on whole milk. Scientific trials and practical experience alike show that with proper feeding calves changed to skim milk when but a few weeks old develop into just as good cows as those fed whole milk until weaning time. Due to the removal of most of the fat, skim milk contains a much larger proportion of protein than whole milk, and has a nutritive ratio of 1:1.5 compared with 1:4.4 for unskimmed milk. Accordingly, in choosing supplements to feed with skim milk the need is not for additional protein, but for an abundance of energy-giving, easily digested carbohydrates or fat to replace the fat removed from the whole milk. While various fats and oils may be used to supplement skim milk, the cereal grains, rich in carbohydrates, are cheaper and more satisfactory for calf feeding.

Starting the calf on whole milk.—The skim-milk calf is usually allowed to get its milk from the dam for 2 or 3 days, tho many dairymen claim that if never allowed to draw milk from the mother, it learns more readily to drink from the pail. In any event, the calf should always get the first milk, or colostrum, which is designed by Nature for cleansing the bowels and starting the digestive functions.

If the cow is a heavy milker the calf should not be allowed to gorge lest scours result. After each feeding the cow should be stripped clean. When the cow's udder is caked, leaving the calf with her will aid in reducing inflammation.

The calf is best taught to drink milk from the pail by using the fingers. If it goes 12 to 24 hours without being fed, or until it becomes genuinely hungry, much less difficulty will be experienced in the first lesson. Many of the calf feeding devices on the market are unsatisfactory, and all are dangerous unless extreme care is exercised in cleansing and sterilizing them.

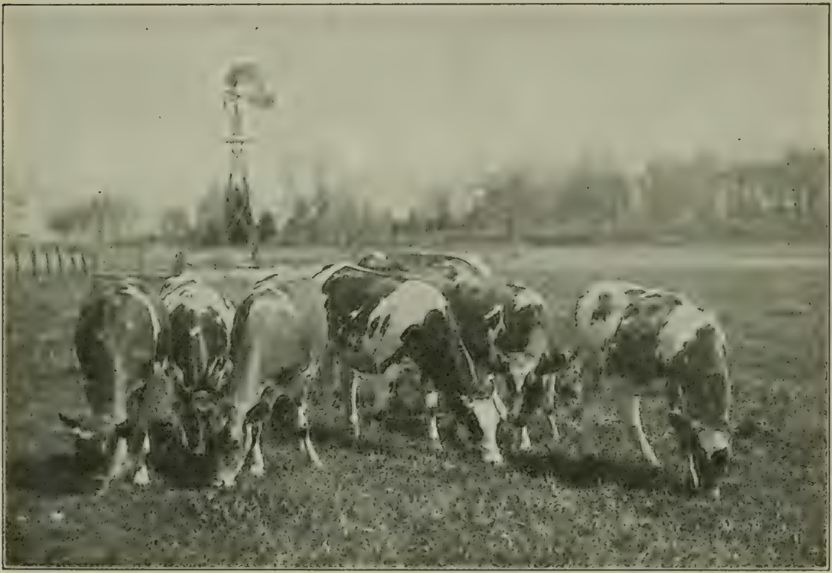

FIG. 78.—THRIFTY, PROMISING HEIFERS RAISED ON SKIM MILK

With proper feeding and care, skim milk calves develop into just as good cows as those fed whole milk until weaning time. (From Wisconsin Station.)

The young calf has a small stomach and naturally takes milk frequently and in small quantities. Too large an allowance of milk produces indigestion and scours. For the first day or two only 5 to 6 lbs. should be fed, or somewhat more for a large, lusty calf, the allowance being divided between 2 feedings, tho some advocate feeding 3 or 4 times a day at first. The milk should be as fresh as possible and at blood heat, as determined by a thermometer. The allowance of milk should be gradually increased, but over-feeding, a common cause of poor success in calf rearing, should be avoided. A safe rule is always to keep the calf a little hungry. Calves should be fed individually, the allowance for each being measured or weighed, and the amount fed depending on the size and vigor of the individual. Guernsey and Jersey calves require not over 8 to 10 lbs. daily for the first 3 to 4 weeks, and those of the larger breeds not over 10 to 12 lbs.

Feeding skim milk.—When the calf is from 2 to 4 weeks old, skim milk may gradually replace the whole milk at the rate of 0.5 to 1 lb. per day, a week or 10 days being required for the change. With very rich milk, some prefer to dilute with skim milk from the start. A few breeders feed some whole milk for as long as 2 months.

After changing to skim milk the allowance may be increased gradually, but should not exceed 18 lbs. daily until the calf is 6 weeks old, and only in rare cases should over 20 lbs. daily be fed. Skim milk is at its best when, still warm, it goes at once from the farm separator to the calf. Milk held for any length of time or chilled should always be warmed to blood temperature, or about 100° F., before feeding. When the calf is 3 to 4 months old it may be accustomed to cooler milk provided the temperature is reasonably uniform. The pails in which the milk is fed should be kept scrupulously clean. Feeding cold skim milk or that which is sour, stale, and swarming with undesirable bacteria is the common cause of scours. Patrons of creameries should insist that all skim milk be pasteurized before it is returned to the farm. This precaution not only keeps the milk sweet longer but it kills the disease-producing bacteria, thereby lessening trouble from scours and preventing the possible introduction of tuberculosis. Skim-milk feeding should usually continue for 8 to 10 months, but when the supply of milk is scant a thrifty calf may be weaned after 3 months, provided good substitutes for milk are fed, as shown later.

At feeding time hand-reared calves should be confined in stanchions, to remain for a time after the milk is drunk until they consume their concentrate allowance and overcome the desire to suck each other's ears or udders. When this precaution is neglected, the shape of the udder may be injured or a heifer may later persist in sucking herself or others.

Feeding concentrates.—When 1 to 2 weeks old the calf should be taught to eat concentrates. Such feeds as corn meal, sieved ground oats, barley meal, kafir meal, wheat bran, red dog flour, and linseed meal, alone or in mixture, may be placed in the bottom of the pail after the calf has finished drinking its milk. Some add the concentrates to the milk, but this is inadvisable for the meal is then less thoroly mixed with the saliva. The addition of such concentrates as bran or linseed meal to the farm grains may be helpful in teaching the calf to eat. The dull calf may be taught to eat the meal by rubbing a little on its muzzle when it is thru drinking milk. Having learned the taste of the meal, the calf should be fed its allowance dry from a convenient feed box. Until it becomes accustomed to the new article of diet, a supply of meal may be kept before it. After this, only as much should be fed as will be eaten up, and the feed box should be cleaned out regularly. At 6 weeks the calf will usually eat 0.5 lb. of concentrates a day; at 2 months, about 1 lb.; and at 3 months, 2 lbs. Unless it is desired to push the animal ahead rapidly no more than this need be fed the skim-milk calf up to 6 months.[1]

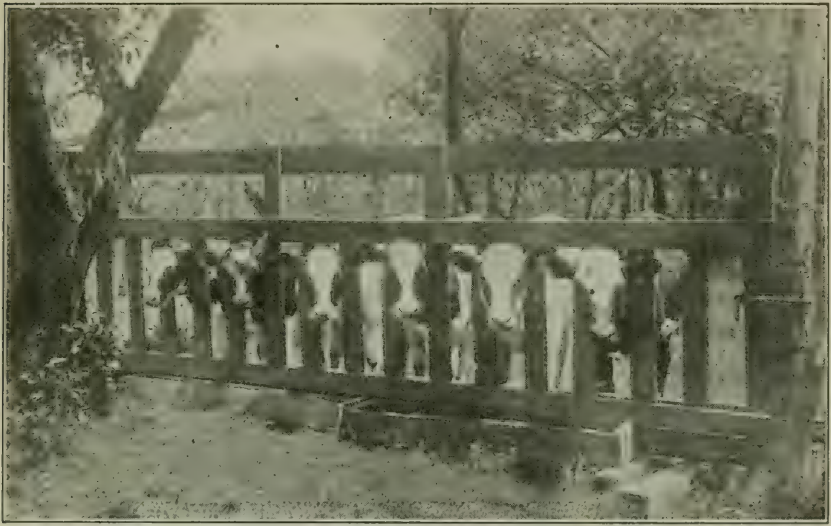

Fig. 79.—Home-Made Stanchions for Calves

Calves should be confined in stanchions at feeding time until they eat their concentrates and overcome the desire to suck each others ears or udders. (From Wisconsin Station.)

Concentrates for skim-milk calves.—Since skim milk is very rich in protein, it is not necessary to use protein-rich feeds, such as linseed or flaxseed meal, as concentrates for skim-milk calves. The farm-grown grains, such as corn, oats, barley, and kafir, give fully as good results and are ordinarily the cheapest concentrates available. Mixing small amounts of such well-liked feeds as linseed meal or bran with the grain may sometimes be advantageous to make the ration more palatable. In teaching calves to eat, ground grain is usually fed, but later whole corn or oats gives as good or even better results than the ground grain. When the calves are several months old, they chew their feed less thoroly and grinding oats or corn may then be profitable. Barley and kafir should always be ground.

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[1] Eckles. Dairy Cattle and Milk Production, p 184.

The following list by Otis [2] will aid dairymen in selecting feeds for skim-milk calves:

"1. Corn meal gradually changed in 4 to 6 weeks to shelled corn with or without bran.

"2. Whole oats and bran.

"3. Whole oats and corn chop, the latter gradually replaced by shelled corn in 4 to 6 weeks.

"4. Ground barley with bran or shelled corn.

"5. Shelled corn and ground kafir or sorghum.

"6. Whole oats, ground barley, and bran.

"7. A mixture of 20 lbs. of corn meal, 20 lbs. of oat meal, 20 lbs. of oil meal, 10 lbs. of blood meal, and 5 lbs. of bone meal, changed to corn, oats, and bran when calves are 3 months old.

"8. A mixture of 5 lbs. whole oats, 3 lbs. bran, 1 lb. corn meal, and 1 lb. of linseed meal."

Ground soybeans are unsatisfactory for calves on account of their laxative action. Cottonseed meal is not a safe feed for young calves, but after they are 6 to 8 months old they may be started on an allowance of 0.5 lb. per head daily and this may be gradually increased to 2 lbs., when fed with silage and such feeds as shredded corn stover and oat straw. Dried blood is helpful for sickly calves.

Hay for calves.—Calves begin to eat hay at about the same age as they do grain, consuming nearly the same quantity of each at first. As they grow and the paunch develops, the proportion of roughage to concentrates should be increased until when 6 months old they will be consuming about 3 times as much hay as grain. The majority of dairymen prefer clover or alfalfa hay, but the allowance of these should be restricted when the calves are young, to avoid scouring. Some prefer bluegrass, native, or mixed hay for the first two or three months because with these there is less danger from scours. The growing heifer should be encouraged to eat a goodly amount of hay in order to develop the roomy digestive tract desired in the dairy cow. Uneaten roughage should be removed from the rack or manger before the next feeding time, for calves dislike hay which has been "blown on."

Succulent feeds.—A small amount of silage from well-matured corn, free from mold, may be fed to calves when 6 to 8 weeks old, only the leaves being offered at first. From a handful twice a day the allowance of silage may be gradually increased until the calves are getting 10 lbs. per head daily when a year old.

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[2] Wis. Bul. 192.

Roots are also a satisfactory succulent feed, and pasture is excellent for calves old enough to make good use of it. To avoid scours, they should be accustomed to grass gradually, being turned to pasture for only an hour the first day. Another method is to accustom them to green feed by giving increasing allowances of soilage before turning to pasture. It is well not to turn spring or summer calves to pasture until they are 2 to 4 months old, for there is less trouble from scours and the young things suffer less from the flies and heat.

Birth weights and gains of calves.—The average birth weight of calves of the leading dairy breeds is as follows: Jersey, 55 lbs.; Guernsey, 71; Ayrshire, 76; and Holstein, 89. Bull calves are heavier than heifers, and calves from mature cows are somewhat heavier at birth than those from heifers.

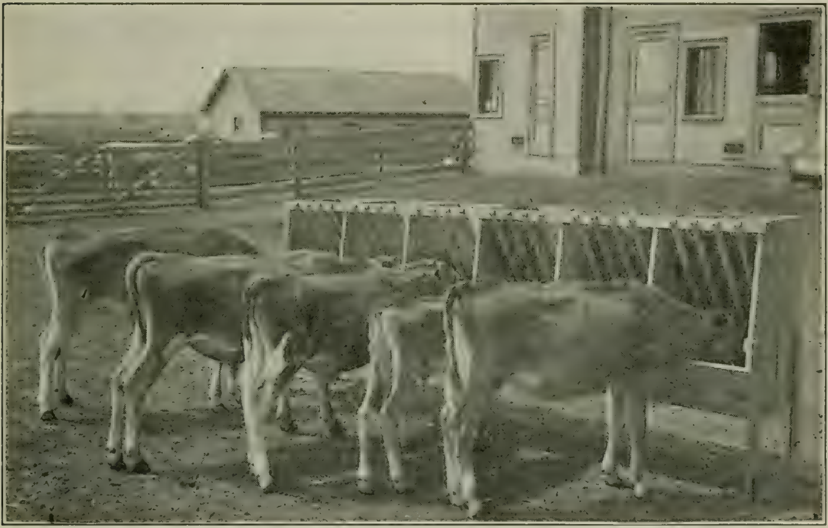

FIG. 80.—RACK AND TROUGH FOR FEEDING HAY AND GRAIN

The growing heifer should be encouraged to eat plenty of roughage in order to develop a roomy digestive tract. (From *Hoard's Dairyman.*)

Properly fed on skim milk, along with suitable grains and roughage, the thrifty calf should gain about 1.5 lbs. daily for the first 4 to 6 months. The aim should be not to fatten the calf but to keep it in a vigorous, growing condition.

Calves should be amply supplied with pure, fresh water, a point which is often neglected, and as soon as they begin to eat grain and hay they should get salt, the same as do older animals.

II. Raising Calves on Skim-milk Substitutes

With dairymen who produce milk for city consumption, for cheese making, or for the condenseries, the rearing of calves on skim-milk substitutes is of great importance.

Buttermilk and whey.—Fresh buttermilk is perhaps the best substitute for skim milk, but the watery slop sometimes obtained from creameries, often from filthy tanks, is almost sure to cause scours. The whey usually obtained from the cheese factory, acid and often loaded with germs that cause indigestion, is unsuited for calf feeding. Sweet, undiluted whey which has been pasteurized may give fair results when fed under the strictest rules as to quantity, regularity of feeding, and cleanliness of the vessels employed. It should be remembered that, instead of being a protein-rich food like skim milk, whey is relatively poor in this nutrient. Accordingly, instead of the cereal grains, feeds high in protein, such as wheat bran, wheat middlings, and linseed meal, should be fed with it.

Feeding a minimum amount of milk.—In trials at the Illinois Station[3] it was found that after the dam's milk was usable calves could be raised successfully on a total of only 137 to 167 lbs. of whole milk and 378 to 491 lbs. of skim milk, with good clover hay and such concentrates as bran, oats, linseed meal, and corn. The method used was as follows:

> The calves were fed whole milk for the first 4 days, and then, starting with the fifth day, 10 lbs. of whole milk and 2 lbs. of skim milk was fed daily per calf for about 10 days, after which the whole milk was gradually replaced with skim milk at the rate of 1 lb. per day. Each calf was then fed 12 lbs. of skim milk per day for 20 days, or until 45 days old, when the allowance was reduced 1 lb. each day, no milk being fed after the calves were about 56 days old. The calves were rather thin for a time, but after being kept on pasture with a limited allowance of grain until 6 months old all were in good thrifty condition, and later several developed into good-producing cows.

Substitutes for milk.—Various concentrate mixtures have been used successfully as substitutes for milk, the calves being fed whole milk for only a few days and then being gradually changed to the substitutes. The Pennsylvania Station[4] secured good results with a home-mixed calf meal, composed of 30 parts wheat flour, 25 parts cocoanut meal, 20 parts skim-milk powder, 10 parts linseed meal, and 2 parts dried blood, the mixture costing about 3 cents per pound. One pound of the mixture was added to 6 lbs. of hot water, and after stirring was cooled to blood heat before feeding. A mixture of equal parts of hominy meal, linseed meal, red dog flour, and blood meal has proven excellent at the Indiana Station.[5] As calves grow older, farm-grown grains, as corn and oats, should be fed in addition to the calf meal, and finally replace it. There are on the market several calf meals, which are more or less complex mixtures of such feeds as linseed meal or flaxseed meal, ground cereals, and wheat by-products, with or without dried milk, casein, and mild drugs. They are fairly satisfactory substitutes for skim milk, but often give no better returns than home-mixed meals that are less expensive.

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[3] Fraser and Brand, Ill. Bul. 164.

[4] Hayward, Penn. Bul. 60

Scours.—The most frequent trouble in raising calves by hand is indigestion, or common scours. This is usually caused by over-feeding, by the use of cold milk or that laden with disease germs, by dirty pails or feed boxes, by keeping calves in dark, dirty, poorly-ventilated stalls, or by feeding improper concentrates, or allowing uneaten feed to spoil in the feed box. Each animal should be watched closely for signs of scours, for a severe case gives the calf a set-back from which it recovers but slowly. At the first indication of trouble the ration should be reduced to less than half the usual amount. Such remedies as castor oil, formalin, and a mixture of salol and bismuth subnitrate are used with success by dairymen.

Common scours should be distinguished from contagious, or white, scours, also called calf cholera, which is due to an infection of the navel soon after birth. This serious disease may usually be avoided by providing that the calf be dropped in a clean stall or on pasture. When the calf is born in the barn, it is best to wet the navel thoroly with a disinfectant, such as a weak solution of creoline, zenoleum, or bichloride of mercury.

III. Dairy Heifers; The Bull

Feed and care of heifers.—Rearing heifers after they are 6 to 8 months old is an easy task, and doubtless for this reason many are stunted for lack of suitable attention and fail to develop into as profitable cows as they otherwise would. Heifers on good pasture usually require no additional feed. In winter there is no better ration than legume hay, silage, and sufficient grain to keep them thrifty and growing without becoming fat. The ration should supply an abundance of protein and mineral matter, and hence unless legume hay forms the roughage the concentrate allowance should be richer in protein than advised for skim-milk calves. From 2 to 3 lbs. of concentrates with 8 to 10 lbs. of legume hay and 12 to 20 lbs. of silage, or 12 to 15 lbs. of legume hay alone, if no silage is available, will keep them growing thriftily the second year when not on pasture.

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[5] Caldwell, information to the authors.

The age at which heifers should drop their first calf depends on the breed and the size and development of the individual. Jerseys and Guernseys which have been well-fed are usually bred to calve at 24 to 30 months of age, while the slower maturing Holsteins, Ayrshires, or Brown Swiss should not calve until 30 to 36 months old.

The cost of raising heifers will vary in different regions, depending on the prices of feed, labor, etc. In trials in Connecticut[6] and Wisconsin[7] the total cost of raising grade heifers to 2 years of age, including cost of calf, feed, labor, and barn rent, insurance, and taxes, but allowing credit for the value of the manure produced, was from $61 to over $66 per head. Some of these items are often not taken into consideration by the dairyman in estimating how much it costs to raise heifers. These trials show that while it certainly pays to raise well-bred heifer calves, it is far from profitable to raise those from inferior dams and sires.

The bull.—The same principles apply in raising bull calves as to heifers, except that after 6 months of age they should be fed somewhat more grain. The bull should be sufficiently mature for very light service at 10 to 12 months of age. He should be halter broken as a calf and when about 1 year old should have a stout ring inserted in his nose. He should be so handled from calfhood that he will recognize man as his master and should never be given an opportunity to learn his great strength. Stall and fences should always be so strongly built that there is no possibility of his learning how to break loose.

Feed and care of the bull.—The ration for the bull in full service should be about the same as for a dairy cow in milk. He should be given good legume hay or hay from mixed legumes and grasses and fed from 4 to 8 lbs. of concentrates, supplying an ample amount of protein. When idle or but in partial service less concentrates will be required. The bull may be fed 10 to 15 lbs. of good corn silage each day[8] but more is said to injure his breeding powers. The bull should be tied by a strong halter to one end of the manger and by his ring to the other end, so that the attendant may approach him from either side without danger. The bull should be dehorned and should always be handled with a strong, safe staff. Even with a quiet, peaceable bull safety lies only in handling him without displaying fear and yet as if he were watching for an opportunity to gore his attendant. Nearly all the accidents occur with "quiet" bulls that have been too much trusted.

[6] Trueman, Conn. (Storrs) Bul. 63.

[7] Bennett and Cooper, U. S. Dept. Agr. Bul. 49.

[8] Hoard's Dairyman, 46, 1914, p. 339.

To maintain health and virility, the bull must have ample exercise. This is perhaps most conveniently furnished by a tread power, where he may run the separator, pump water, do other useful work, or run the power for exercise only. Many declare that the purchase of a tread power merely to furnish exercise for the bull is a wise investment. Others fix a long sweep on a post and tie the bull at the end, allowing him to walk around the circle. Another device is a light cable stretched between 2 high posts, the bull being attached to it by a sliding chain so that he is able to walk back and forth the length of the cable. The bull may also be harnessed and hitched to cart or wagon for such odd jobs as hauling manure or feed.

QUESTIONS

1. Why should dairymen rear the heifer calves from their best cows?
2. Describe the manner in which you would feed a skim-milk calf from birth.
3. Name several concentrates or mixtures of concentrates satisfactory for feeding to calves being raised on skim milk.
4. Tell about the hays and succulent feeds useful for calf feeding.
5. What is the average birth weight of calves of the four leading dairy breeds, and how large gains should well-fed calves make?
6. Name the most common causes of trouble with skim-milk fed calves.
7. Discuss the feeding of buttermilk and whey to calves.
8. How may calves be raised on but a minimum of milk?
9. Give the ingredients in a satisfactory calf meal.
10. How may common scours and contagious scours usually be prevented?
11. Discuss the feeding and care of dairy heifers; of the bull.

CHAPTER XXIII

FEEDING AND CARE OF BEEF CATTLE

I. Factors Influencing Beef Production

In 1900 there were about 660 cattle, other than milch cows, per 1,000 inhabitants in this country, but in 1910 the number had decreased to 450. Later the war-time urge for more beef for export has caused a temporary increase in the number of beef cattle. Among the reasons for the failure of the number of beef cattle to keep pace with population are the breaking up of the western ranges into farms, the high prices for grain and the consequent tendency of farmers to sell their crops rather than feed them to stock, the increase of tenant farmers, who often lack capital to stock their farms properly, the expansion of dairying due to the increasing demand for dairy products, and the fact that not infrequently the fat steer is sold at a loss.

Fortunately for the American public, our experiment stations are pointing out how the cost of beef production may be brought down to where it may yield a reasonable profit to the farmer without the finished product being unduly costly to the consumer. The trials reviewed in these chapters show how the breeding herd may be maintained cheaply by utilizing the roughage which would otherwise be wasted on the farm, and the steer finished for market on a smaller allowance of concentrates than was formerly believed necessary.

Phases of beef production.—Tho many cattle are still fattened by the farmers who raise them, beef production has naturally become separated to a considerable extent into two distinct phases. In regions where the land is unsuited for tillage, due either to its rough nature or the scant rainfall, breeding herds are maintained and the increase, raised chiefly on the cheap pasturage, sold as feeder steers. On the other hand, in the corn belt, where corn is cheap compared with pasturage, the majority of the steers fattened are shipped in from the range districts, where they can be raised at less cost. A few years ago the steer feeding business had largely passed into the hands of professional feeders who fattened several carloads each year. In many instances they made little use of the manure produced and purchased much of their feed. On such a basis the enterprise was largely speculative. Fortunately, the practice has increased for farmers to fatten a carload or two of steers each year to provide a farm market for grain and roughage and thus conserve the soil fertility.

Margin.—Under usual conditions, the feed consumed by fattening cattle or sheep per 100 lbs. of gain costs more than the selling price per cwt. of the finished animal. With normal market conditions, this difference is offset by the fattened animals selling for a higher price per 100 lbs. than was paid for the same animals as feeders. The difference between the cost per cwt. of the feeder and the selling price per cwt. of the same animal when fattened is called the *margin.* The principle of the margin may be illustrated thus: If a 900-lb. steer costs $7.00 per cwt. when placed in the feed lot, its total cost is $63.00. If during fattening it gains 300 lbs. at a feed cost of $36.00, each cwt. of gain has cost $12.00. Assuming that the manure produced by the steers and the pork made by the pigs following the steers will pay for the labor and the miscellaneous expenses, the steer, now weighing 1,200 lbs., has cost $99.00 and accordingly must bring $8.25 per cwt. at the feed lot to even the transaction. The margin will be $1.25, the difference between $8.25 and $7.00. Due to the high cost of the gains, a margin is usually necessary in fattening cattle or sheep to make a profit or "break even."

The factors which determine the margin needed in fattening are: (1) the initial cost of the cattle; (2) their initial weight; (3) the cost of the gains; and (4) the expense of getting the steers to the feed lot and then to the market, when finished.

Other conditions remaining the same, the higher the initial cost or purchase price of the feeder the narrower, or smaller, is the necessary margin. For example, let us assume that this same steer had cost $9.00 per cwt. when placed in the feed lot in place of $7.00 per cwt. Making the same gain as before and at the same cost for feed, it would have to sell for $117.00, or $9.75 per cwt., to break even on the transaction. The necessary margin would then be $9.75 minus $7.00, or only $.75 per cwt.

The heavier the animal is when placed on feed the narrower will be the necessary margin, for the increased selling price is secured for a greater number of pounds of initial weight. This factor may be offset, as is shown later, if the heavier cattle are older and hence make more expensive gains.

It is evident that any factor which increases the feed cost of the gains makes necessary a wider margin. The necessary margin is thus greater when feeds are high in price, and also with mature animals than with younger ones, which make more economical gains. Since gains made on grass are usually cheaper than in the dry lot, a wider margin is required for winter feeding than in fattening animals on pasture. The higher the degree of finish, or fatness, the more expensive the gains become and the wider the necessary margin.

Feed requirements for fattening cattle.—In Chapter V we have already seen that with mature animals there is comparatively little storage of protein or mineral matter during fattening and that the ration may have a relatively wide nutritive ratio. However, most of the beef cattle in this country are now fattened before they are full-grown. For the fattening of such animals sufficient protein must be provided for the growth in muscle and other protein tissues which takes place as the animals fatten. From an extensive survey of feeding trials at the experiment stations, the authors believe that for the most rapid gains in fattening 2-year-old steers the nutritive ratio should not be wider than 1:7 to 1:7.8. (See Appendix Table V.) When protein-rich feeds are lower in price than carbonaceous feeds, it may be economical to feed much narrower rations than this. For example, good results are secured when cottonseed meal is fed as the only concentrate, the nutritive ratio then being as narrow as 1:3.8. As is shown later in this chapter, the amount of concentrates to be fed will depend on the rapidity with which it is desired to fatten the cattle, and the degree of finish or fatness which the demands of the market make most profitable.

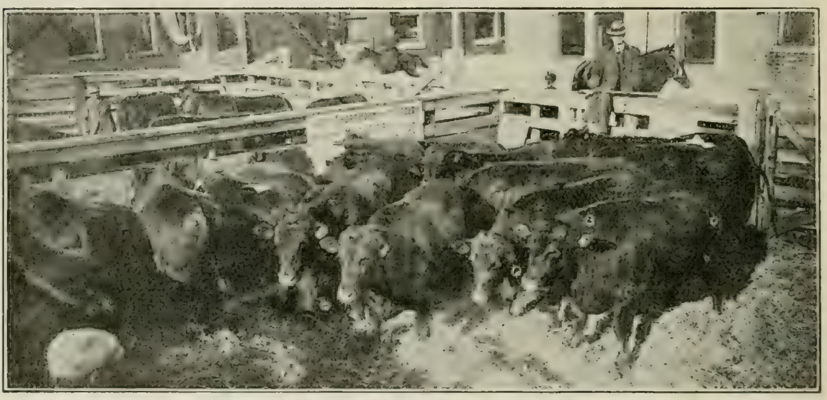

FIG. 81.—CHAMPIONSHIP YEARLING FAT STEERS AT THE INTERNATIONAL

Yearlings usually make less expensive gains than older steers, but require a somewhat longer feeding period to reach the same finish.

Influence of age on cost of fattening.—In Chapter V we have already seen that young, growing animals make much larger gains from each 100 lbs. of feed than those which are more mature. As this subject is of much importance in beef production, many trials have been conducted to compare the economy of gains and the profits from fattening calves, yearlings, 2-year-olds, and older cattle. The following table averages the results secured in two trials of this nature at the Indiana Station[1] with well-bred beef steers fed until they were thoroly fattened.

Fattening calves, yearlings, and 2-year-olds

	Calves	Yearlings	2-yr.-olds
Av. initial weight, lbs.	518	888	1,067
Length of feeding period, months	9	6.5	6
Av. daily gain, lbs.	1.88	2.22	2.6
Av. total gain, lbs.	508	431	471
Feed per 100 lbs. gain by steers:			
Shelled corn, lbs.	596	704	681
Cottonseed meal, lbs.	88	111	108
Clover hay, lbs.	168	165	160
Corn silage, lbs.	385	660	573
Feed cost per 100 lbs. gain *	$7.74	$9.09	$9.37
Pork per bushel of corn fed to steers, lbs.*	1.00	1.85	2.50

* Av. of 3 trials.

While it required only 6 months to make the 2-year-old steers fat enough to sell as prime beeves, it took 9 months to finish the rapidly growing calves equally well. Tho the daily gain per head increased with the age of the steers, the older ones required considerably more feed per 100 lbs. gain, and thus made more expensive gains. Other trials have shown that the gains of 3-year-olds are still more expensive than those of 2-year-olds. As is usual, the older steers in this trial masticated the shelled corn less thoroly, and hence the pigs following them made more pork from each bushel of corn fed the steers.

Calves usually cost more per 100 lbs. as feeders than do yearlings or 2-year-olds, but when fat sell at about the same price per 100 lbs. as the older animals. This may entirely offset the cheaper gains made by them. For example, in these trials the 2-year-olds returned the largest and the calves the smallest profit per head. In addition, greater care and skill are required to fatten calves, they do not stand severe weather so well, and must be fed a larger proportion of grain to roughage than the more mature feeders. For these reasons, the great majority of experienced farmers who buy feeder steers to fatten prefer 2-year-olds. On the other hand, many farmers who raise their own steers on high-priced land find it most profitable to produce baby beef, selling the animals when 18 months old or less.

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[1] Skinner and Cochel, Ind. Bul. 146.

Influence of degree of finish.—Impelled by a hearty appetite, under liberal feeding the steer at first lays on fat rapidly, storing it everywhere within the body. When it has become fairly well-fleshed the appetite loses its edge, and the steer shows a daintiness in taking his food not at first noticed. Every pound of increase now takes more feed than formerly. This is not only because the steer eats less feed per 1,000 lbs. body weight and hence has less available for making body tissue, but also because gains at the close of the fattening period are more concentrated; i.e., contain less water and a larger proportion of fat. The fattening process may be likened to inflating a football—the operation, easy and rapid at first, grows more and more difficult until the limit is reached.

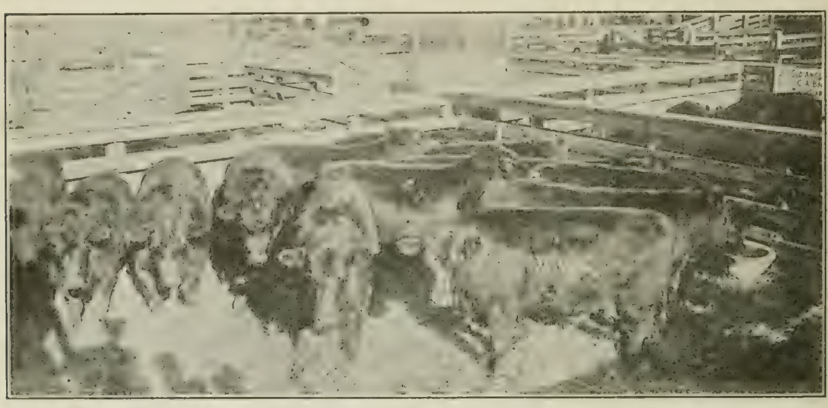

FIG. 82.—CHAMPIONSHIP 2-YEAR-OLD FAT STEERS AT THE INTERNATIONAL

The great majority of experienced farmers who buy feeder steers to fatten prefer 2-year-olds. Many of those who raise their own feeders on high-priced land find it more profitable to fatten the animals as baby beef.

Tho the large markets demand well-fatted steers, to meet the demand it is not necessary to carry them to extreme fatness, which means exceedingly expensive gains. The wise feeder will therefore watch the market and sell his animals as soon as they are sufficiently finished to meet its demands, unless a probable decided advance in price warrants holding them longer. At this stage sufficient fat will have been deposited between the bundles of muscle fibers to give the characteristic ''marbled'' appearance and make the meat more tender and palatable. As we have seen in Chapter V, this is the primary object of fattening meat-producing animals.

Length of feeding period.—The length of the feeding period needed to finish cattle depends on the method of feeding followed and on the age and condition of the cattle when placed on feed. When the steers are fed roughage with only a limited allowance of concentrates, the fattening process will take considerably longer than where they are rapidly brought to full feed and then crowded with all the concentrates they will eat. Obviously, much less time is required to finish steers already in good flesh when started on feed than those in leaner condition. Such fleshy feeders are commonly "short-fed;" i.e., fed for 90 to 100 days or less on a heavy allowance of concentrates. Thin steers must be "long-fed;" i.e., fed for a considerably longer period, during the first part of which often little or no grain is fed other than that in the silage.

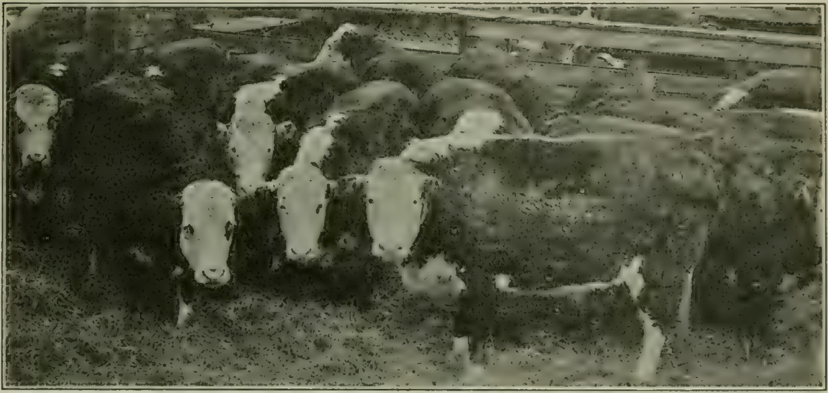

FIG. 83.—CHAMPIONSHIP 3-YEAR-OLD STEERS AT THE INTERNATIONAL

Steers of this age are continually becoming more scarce on the market, due to the fact that they produce beef less economically than younger animals.

As we have already seen, the younger the steers are, the longer they must be fed to reach a given finish. While it ordinarily requires 3 to 4 months to finish mature steers and 4 to 7 months for 2-year-olds, it takes 9 months or longer to fatten calves.

Limiting the concentrate allowance.—To reduce the amount of grain required, cattle are often fed hay and silage during the first part of the fattening period, with but little or no concentrates, even if they are later finished on all the concentrates they will eat. Whether this system will be more profitable than bringing the cattle rapidly to a full feed of concentrates, depends on the relative cost of roughages and concentrates. In three trials at the Indiana Station [2] the steers in one lot were fed only clover hay and corn silage, during the first 60 to 70 days, or else clover hay, corn silage, and 2.5 lbs. of cottonseed meal per 1,000 lbs. live weight in addition to balance the ration, and were then finished on the same feeds with all the corn they would eat. Another lot was fed an unlimited allowance of corn from the first. Tho the steers in the first lot made slightly cheaper gains, they returned less profit than those fed all the corn they would eat. On the other hand, in trials at the Pennsylvania[3] and Iowa[4] Stations, limiting the allowance of concentrates during the first of the fattening period returned larger profits.

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[2] Skinner and King, Ind. Buls. 153, 163, 167.

In former years steers were commonly finished on all the corn or other concentrates they would eat, but with feeds at the high prices during 1917 to 1920, it was frequently more profitable to restrict the allowance of concentrates, even during the latter part of the fattening period. In fattening steers 2 years old or more, the most profit could then often be made, even in the corn belt, on a ration of well-eared corn silage, hay, and enough linseed or cottonseed meal to balance the ration, but with no corn grain except that in the silage. The amount of concentrates to be fed should be governed by the relative prices of concentrates and roughages, by the difference in price paid for well-finished cattle and for those carrying only a moderate amount of fat, and by the length of time before it is desired to have the cattle ready for market. (See Pages 318-19.)

Value of breed in beef making.—Experience teaches that "blood tells" in beef production, but the reasons commonly given for the superiority of beef-bred animals are not all valid. Occasionally, the claim is yet made that well-bred beef cattle eat less than scrubs. Feeding trials have shown instead that they are heartier eaters, for they have greater ability to digest feed and economically convert it into meat, and consequently make more rapid gains than scrubs. Dairy-bred steers, especially those of the larger breeds, may make as large gains as beef-bred steers. This is reasonable, for in developing both beef and dairy breeds one of the chief objects has been to secure animals with large capacity for utilizing feed. In this the scrub is apt to be lacking.

Experienced feeders know that beef-bred steers "mature" or become well fattened earlier than others. Indeed, only blocky calves of beef conformation are suited for early fattening as baby beef. Tho dairy steers grow rapidly, they do not become well finished at an early age. Other important points of superiority for beef-bred

[3] Cochel, Penn. Bul. 118; and Tomhave, information to the authors.

[4] Pew, Evvard, and Dunn, Iowa Bul. 182.

steers over scrubs and those of the dairy breeds are that they yield a higher percentage of dressed carcass, with less internal fat, which brings a low price, and a somewhat higher percentage of loins and ribs, the most valuable cuts. Moreover, the thick-fleshed cuts from well-finished beef steers are superior in quality to the thin-fleshed cuts of steers lacking beef blood, and consequently bring a higher price on discriminating markets.

For the beef producer who raises the animals he fattens, it is evident that well-bred specimens of the beef breeds are the most profitable. The question is more complicated for one who purchases feeders on the market. He must consider the price at which he can secure the various grades and their probable selling price when fattened. Opportunities for larger profits and larger losses as well lie with the better grades of feeders. The beginner is therefore wise in first handling feeders of the commoner kinds, which must be purchased at correspondingly lower prices, since the margin for profit in feeding low-grade cattle is usually small.

Shelter.—Trials at several stations in which steers have been fattened in open sheds with adjacent yards in comparison with others housed in barns show that the fattening steer, consuming an abundant ration, a considerable portion of which is roughage, has no need for warm winter quarters. With such animals sufficient heat is produced in the body thru the mastication, digestion, and assimilation of the food to keep them warm under all ordinary weather conditions, without diminishing the amount of net nutrients available for fattening. A reasonable degree of cold is a benefit rather than a detriment, providing the coats of the animals are kept dry. Feeding in open yards with no shelter other than windbreaks is common in western sections with little rainfall, even in regions with rigorous winters. For humid regions with severe winters an open shed should be provided where the animals may find shelter from storms. In the South where the winters are mild the saving thru providing shelter may not be sufficient to warrant the expense.

The self feeder.—By the use of a self feeder, a large box or bin so arranged that the grain passes down into the feed trough as rapidly as it is consumed, it is necessary to supply fattening cattle with concentrates only twice a week. In a trial at the Illinois Station[5] one lot of steers was fed whole clover hay and a concentrate mixture of 7 parts ground corn and 1 part linseed meal separately at regular feeding periods twice daily, while another was supplied chaffed (cut) hay mixed with the concentrates, the whole being fed in a self feeder to which the cattle had access at all times.

[5] Mumford and Allison, Ill. Bul. 142.

The self-fed steers consumed a heavier concentrate allowance and were brought to full feed in a shorter time without any set back from over-eating. Tho consuming more feed than Lot I, this was more than offset by their larger gains. Even after adding the cost of chaffing the hay, the self-fed steers made the cheaper gains. Both systems required about the same amount of labor, but by the use of the self feeder the necessity for a man skilled in feeding was reduced. In trials during 2 years at the Iowa Station[6] 2 lots of 2-yr.-old steers were fed for 150 to 160 days on shelled corn, linseed meal, corn silage, and alfalfa hay. Each year one lot was fed the corn in a self feeder and the other by hand. The self-fed steers made slightly the larger gains and returned the most profit over cost of feed.

FIG. 84.—QUIET IS HIGHLY IMPORTANT IN MAKING BEEF

Cattle which "eat and lie down" make much more economical gains than those which are restless and active. (From *Breeder's Gazette.*)

Water; salt.—Fattening cattle should have an abundant supply of pure water at all times. Separate water troughs should be provided for pigs running with the steers. While it is best to have water

[6] Pew, Evvard, and Dunn, Iowa Bul. 182.

before cattle at all times, they readily adapt themselves to taking a fill once daily and thrive. The water provision should not be less than 10 gallons per day per head for mature cattle.

Animals consuming large quantities of rich, nutritious food, as are fattening steers, show a strong desire for salt, and this craving should be reasonably satisfied.

Hints on fattening cattle.—In fattening cattle it is important that they be accustomed to corn or other concentrates gradually or digestive trouble will result. At first give all the roughage they will clean up, with but 2 lbs. of concentrates per head daily, increasing 1 lb. or less each day until 10 lbs. is fed. Any further increase should be still more gradual. The majority of cattlemen feed concentrates and roughage twice a day in winter and once a day on pasture in summer.

The best results are secured only when the cattle are fed at regular hours and when the attendant is quiet and kind at all times, so that the animals trust rather than fear him. In parts of the corn belt the feed lot in winter is often a sea of mud. Under such conditions the steers cannot be expected to make the best gains. Cattle of the same age, or at least those of equal size and strength, should be fed in the same enclosure. Weak animals, and those unable for any reason to crowd to the feed trough and get their share, should be placed where they can eat in quiet. The expert stockman quickly notes any tendency to scour, and checks it by reducing the allowance of concentrates. He has a quick eye which takes in every animal in the feed lot at a glance, and a sound judgment which guides in dealing out feed ample for all, but not a pound in excess.

Pigs following steers.[7]—Pigs are usually kept with fattening cattle to utilize the undigested corn or other grain in the droppings. The number of pigs per steer varies with the kind of feed and the age of the cattle being fed. The range is 2 to 3 pigs per steer on snapped corn, about 1.5 per steer on husked ear corn, 1 per steer on shelled corn, and 1 pig to 2 or 3 steers on crushed or ground corn. The younger the steers, the better they masticate and utilize their feed and the smaller are the gains made by the pigs following. The best pigs for following cattle weigh from 50 to 150 lbs. and when they become fat they should be replaced. Any extra grain given the pigs should be fed in nearby separate pens before the cattle are fed, so that they will not crowd around the feed troughs or under the wagon and team when the cattle are being fed. The margin in cattle feeding is frequently so narrow that the gains made by the pigs return the only profit. Therefore, except in the case of young cattle being fed for baby beef on ground grain, it is best not to undertake to fatten cattle unless pigs can follow them and utilize the waste feed.

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[7] Largely adapted from Waters, Mo. Bul. 76.

Cost of fattening.—Mumford[8] estimates that one man and team can care for and feed 200 cattle and the pigs following. From this the cost of labor can readily be computed at local prices. Under favorable conditions the gains of pigs following steers fed whole corn will offset the labor cost of caring for both the fattening steers and the pigs. Another reasonable assumption is that when farm-grown crops are charged to the steers at market prices, the labor of feeding them to the cattle is no greater than that of hauling them to market. The manure produced by steers during 6 months' feeding ranges from 3 to 4 tons, worth on many farms from $9.00 to $13.00 per steer. This alone should repay the labor cost of fattening the cattle.

Preparing for shipment; shrinkage.—A day or two before shipment the cattle should be fed hay only, preferably hay from the grasses or mixed hay, rather than clear clover or alfalfa hay, which are too laxative. For feed while on the road good, sweet hay, with no grain, is best. The shrinkage of either range cattle or fat cattle in transit 36 hours or less is 3 to 4 per ct.; when in transit 70 hours or over the shrinkage is 5 to 6 per ct. of their live weight.[9] When cattle are fed succulent feed up to the time of shipping, the shrinkage is much greater.

II. RAISING BEEF CATTLE

In establishing a breeding herd, the first step should be to select well-bred individuals of the beef breeds, having the conformation which indicates that their off-spring will make economical gains, mature early, and yield carcasses with a large percentage of high-priced cuts of meat. Where cows are kept only for raising calves for beef, the cost of their keep for an entire year must be charged against the fatted steer. In reducing the cost of beef production, it is therefore essential that the breeding herd be maintained as cheaply as possible, yet kept in vigorous breeding condition.

The breeding cows.—Cows kept solely for beef production are commonly grazed on pasture during the growing season, the suckling calves running with their dams. Usually the pastures thus utilized will be land least suited to tillage, and no concentrates will be fed on pasture. Where land is high-priced and tillable the herd may often be maintained most cheaply on limited pasturage supplemented by summer silage. Pure water, salt, and shade should be supplied the herd at pasture.

[8] Beef Production, pp. 33–4.

[9] Ward, U. S. Dept. Agr. Bul. 25.

The herd may be wintered on legume roughage alone, or on carbonaceous roughages with some such nitrogenous concentrate as cottonseed or linseed meal to balance the ration. They should be kept in good flesh else they will not produce vigorous calves and nourish them with a good flow of milk.

At the Illinois Station,[10] an average ration of 16.7 lbs. corn silage, 3.5 lbs. clover hay, and 9.6 lbs. oat straw proved excellent for wintering 860-lb. beef cows, while one of 8.7 lbs. shock corn, 3.5 lbs. clover hay, and 10.8 lbs. oat straw was satisfactory, but not as good as the first ration. At the Pennsylvania Station,[11] 1,160-lb. beef cows, several of which were suckling calves, were wintered satisfactorily on 58 lbs. of corn silage and 1 lb. of cottonseed meal per head daily. During the remainder of the year the cows, with the calves at foot, grazed a pasture too rough for tilled crops.

At the Hays, Kansas, Sub-station,[12] 900-lb. beef cows were wintered on 20 to 35 lbs. of kafir silage or 26 to 27 lbs. of kafir fodder or stover per head daily, with 1 lb. of cottonseed meal and what wheat straw they would eat, 10 to 17 lbs. daily for each animal. The daily feed cost with pre-war prices was only 4 cents per head with kafir silage and 10 cents with kafir fodder. These trials show the possibilities of maintaining beef breeding cows chiefly on cheap roughages.

The beef bull.—On the range the bulls run with the cows, but under farm conditions it is best to confine the bull during the summer, preferably in a well-fenced pasture lot. It will then be possible to keep a record of the date when the cows are due to calve, and the bull so handled can serve a larger number of cows a year. The same general principles apply to the feed and care of the beef bull as with the dairy bull. (See Chapter XXII.)

The beef calf.—Under the simplest method of beef production, as on the range, the calves are dropped in the spring and run with their dams during the summer. Under farm conditions some prefer to allow the calves to suck only at stated intervals, 3 times a day at first, and later twice. Where the calf remains with the dam her udder should, for a time, be stripped night and morning lest neglect bring garget and destroy her usefulness. The greatest danger under this system comes at weaning time, when, if the calf has not been taught to eat solid food, it pines and loses weight. To avoid this, before weaning it should be taught to eat shelled corn, whole oats, wheat bran, linseed meal, hay, etc. The first departure from this

[10] Mumford, Ill. Bul. 111.

[11] Cochel, Tomhave, and Severson, Penn. Bul. 118, and information to the authors.

[12] Cochel, Kan. Bul. 198.

simple and primitive method is putting two calves with each cow, which is feasible where she yields a good flow of milk. Suckling calves should gain 2 lbs., or over, per head daily if their dams are good milkers.

While in some districts it is best to rear the beef calf on whole milk from dam or pail, over large sections of the country it is more profitable to sell the fat of the milk in butter or cream and rear the calf on skim milk with proper supplements. This method involves increased labor, skill, and watchfulness on the part of the feeder, but its success has been widely demonstrated. The method to be employed is like that already given for the rearing of the dairy calf, except that the beef calf should be fed more liberally. Calves that fail to thrive when sucking the cow or when fed on rich milk should have their allowance reduced or should be given part skim milk.

Fig. 85.—A Farm Herd of Beef Cows and Calves

The next few years should see good beef breeding herds established on thousands of farms, to utilize land unsuited for tillage or such cheap feeds as corn silage, corn stover, and straw. (From *Breeder's Gazette.*)

After weaning, growth should be continuous. If the calves are not at pasture, they should be fed plenty of good roughage, with sufficient concentrates to produce the desired gains. As with dairy heifers, for young beef cattle nothing excels good legume hay, rich in protein and bone-building mineral matter. Where this is not available nitrogenous concentrates should balance the ration. The majority of beef producers prefer to have calves dropped in the spring, as the cows may then be wintered more cheaply, with less shelter and less care.

Veal production.—For the highest grade of veal whole milk is essential, and growth must be as rapid as possible, the whole process being completed before there is any tendency in the flesh to take on the coarser character of beef. Such veal commands a high price in some of the European markets, and the butchers are extremely expert in judging whether the calf has received any other feed than whole milk. In this country such veal can be profitably produced only for special markets. A less expensive method is to feed a limited amount of whole milk supplemented by grain, or skim milk may be gradually substituted, as with dairy calves. With the latter method, considerable skill is necessary to feed the calves so they will gain rapidly without going off feed.

Growing beef cattle.—Except where calves are being fattened for baby beef, growing beef cattle are not ordinarily given any feed in addition to good pasture, unless the pasture becomes short. Then summer silage, soiling crops, or specially grown annual pasture crops may be supplied. Considerable fall pasturage is furnished by aftermath on meadows or by the stubble fields, especially where rape seed is sown with the spring grain.

The ration needed to carry growing cattle thru the winter in good condition will depend on their age, and on whether it is desired to have them make substantial gains or merely come thru the winter in thrifty enough condition to make maximum gains on pasture the following summer. While yearlings and 2-year-olds may be wintered on good roughages only, for calves 1 to 3 lbs. of concentrates per head daily is needed in addition, for it is important to keep the calf growing steadily. Calves do not thrive on such coarse roughage as may be fed to older cattle. At the North Platte, Nebraska, Substation,[13] beef calves were wintered satisfactorily on 2 lbs. of corn and oats with alfalfa hay or half alfalfa and half prairie or sorghum hay. Poorer results were secured with prairie or sorghum hay and the same amount of grain. At the Kansas Station,[14] beef calves made good growth in winter on silage from corn, kafir, or sweet sorghum, and 1 lb. of cottonseed or linseed meal per head daily. The second winter, if the cattle are not to be fattened on grass the following summer, the aim should be to grow as large a framework as possible, but not to fatten, for cattle that are lean but thrifty in the spring make larger gains on summer pasture than do fleshy ones.

[13] Snyder, Nebr. Buls. 105, 117.

[14] Cochel, information to the authors.

If the cattle are to be fattened on pasture the following summer, feeding a moderate amount of concentrates in addition to legume hay and silage rich in ear corn will start fattening and help to shorten the summer feeding period.

Trials at the Missouri Station,[15] show that yearling steers fed clover, alfalfa, or cowpea hay with 5.5 to 6.0 lbs. of corn per head daily gained 1.4 to 2.0 lbs. per head daily. Half clover hay and half corn stover gave nearly as good results, but with corn stover, or timothy, sorghum, or millet hay as the only roughage, the results were much poorer. Yearlings wintered on 13.6 lbs. clover hay and 13.6 lbs. corn stover per head daily or on ensiled corn stover alone gained about half a pound per head daily. On cured corn stover alone they lost weight. At the Tennessee Station [16] steers were wintered satisfactorily on corn silage, corn stover, or straw, with 1 to 2 lbs. of cottonseed meal in addition.

III. METHODS OF BEEF PRODUCTION

Fattening cattle on pasture.—Whether the feeder should finish his cattle during the winter and spring in the dry lot or carry them thru the winter to be fattened on pasture in the summer will depend, first of all, on the cost of pasturage compared with hay, silage, and other roughage. In the grazing regions cattle are commonly sold at the close of the pasture season when, if the grass has been good, many are fat enough for the block, while the rest go into feed lots to be fattened further. Where land is high-priced, the tendency is to fatten feeders in the dry lot, since under these conditions corn silage is often cheaper than pasturage.

According to data collected by the experiments stations [17] from successful cattlemen, the gains of cattle in the corn belt on grass and receiving no grain should range from 1.2 to 1.7 lbs. per head daily for yearlings and 1.3 to 1.9 lbs. for 2-year-olds during the grazing season. It was found in Indiana that on the average thruout the season each grain-fed steer required 1.1 acres of pasture, and when no grain was given each steer required 2 acres. From these figures and the price at which pasture land rents, the cost of gains on pasture may be calculated. When cattle are fattened on pasture less grain and less expensive supplements like cottonseed and linseed meal are required than when finished in the winter feed lot. Cattle fatten more rapidly and more uniformly on pasture, and the pigs following them make larger gains. Labor is saved when cattle are fattened on pasture. In summer the grain only is drawn; it is usually fed but once a day; there is no roughage to handle; and the manure is distributed by the cattle themselves.[18]

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[15] Waters, Mo. Bul. 75.

[16] Willson, information to the authors.

[17] Mumford and Hall, Ill. Cir. 79; Waters, Mo. Cir. 24.

Feeding concentrates on pasture.—Cattle being finished on pasture may be fed no concentrates at all, a small allowance may be given during the entire pasture period, concentrates may be fed during only the last few weeks, or, finally, an unlimited allowance of grain may be given thruout the entire period. Except under range conditions and in certain districts, as in the bluegrass region of Virginia, where the grasses are unusually nutritious, it will usually pay to feed some grain in addition to pasture. The cheap gains made on grass alone are usually offset by the low selling value of such cattle, because they are usually not well finished. When grain has been fed to cattle during the winter, it should be continued after turning to pasture until they become accustomed to grass, otherwise they may shrink in weight. If cattle are nearly finished when the pasture season opens, they had best be finished in the dry lot, for if turned to pasture they usually make poor gains.

Since immature grass, such as is usually eaten by grazing animals, is much richer in protein than grass at the stage when cut for hay, corn and bluegrass pasture alone make a fairly well-balanced ration for the fattening steer. Experiments at the Missouri Station[19] show, however, that it is usually advisable to add some protein-rich supplement during the last of the feeding period to keep the steers from going off feed and making smaller gains.

Baby beef.—The most intensive method of beef production is fattening calves for baby beef. Under this system beef-bred calves are fattened as they grow, reaching a good finish when 16 to 18 months old and weighing about 1,100 lbs. or less. In the production of baby beef, first of all, blocky calves of good beef type and conformation must be selected, for scrub or dairy-bred calves will not usually reach the desired maturity and finish at this early age. Profitable baby beef production requires a high degree of experience, judgment, and skill and it is a mistake for the inexperienced to dip heavily into this art. Calves for baby beef should be fattened as they grow, never being allowed to lose their "calf fat." In winter roughage of high quality, such as clover or alfalfa hay and silage, should be supplied and during summer the calves should be on good pasture. Shelled, crushed, or ground corn should be fed, together with linseed meal, cottonseed meal, or other protein-rich concentrates. When whole corn is given, hogs may profitably follow. Oats are one of the best of feeds with which to start the calf on its way to fattening. In

[18] Waters, Mo. Cir. 24.

[19] Mumford, Mo. Bul. 90.

baby beef production the calves must be fattening all the time; this can only be accomplished by the most liberal and judicious feeding, since it is extremely difficult to get calves and yearlings sufficiently fat for the market requirements. Heifer calves mature more quickly and may be marketed earlier than steers. It is seldom possible or profitable to get spring calves ready for the baby beef market before July of the following year and more frequently they are not marketed until October, November, or December, when approximately 18 months old. This system of beef production is best suited to corn-belt farms where pasture is relatively expensive and corn is cheaper than in other sections of the country.

Fattening yearlings.—Less extreme than the feeding of calves for baby beef is finishing steers as yearlings; i.e., before they are 2 years old. Spring calves may be carried thru the first winter on roughage with a small allowance of concentrates, the ration being such as to keep them growing steadily. The second summer good pasture alone will suffice to put them in condition for the feed lot in the fall.

Calves to be fattened as yearlings should be taught to eat grain before being weaned, so that there may be no loss of condition at this time. To fatten yearlings properly requires 8 to 10 months, even if they are of good beef type. Trials at the Indiana Station[20] show that it is ordinarily more profitable to complete the fattening of yearlings in the feed lot, than to turn them out to grass in the spring, when half finished.

Fattening cattle 2 years old or older.—Where pasturage is cheap, cattle are usually not marketed until 2 years old or older, in which case they may be carried thru the first winter chiefly on roughage with 1 to 3 lbs. of grain per head daily. The following summer they will grow well on good pasture without grain. The second winter no grain need be fed, if the cattle are not to be sold until fall or until after finishing in the winter feed lot. If they are to be finished on grass early in the summer, a moderate allowance of concentrates will be needed during the preceding winter to start fattening.

According to Cochel of the Kansas Station,[21] the system of beef production usually most profitable in western Kansas is to raise the calves on pasture the first summer; winter them on kafir, milo, or sorghum silage, alfalfa hay and straw or stover from the sorghums, with perhaps some cottonseed meal in addition; pasture the yearlings the second summer without feeding grain; carry them thru the second winter as before; and market the third summer from grass. With good pasture such cattle should reach a weight of about 1,050 lbs. and be fat enough to sell as fleshy feeders or fair killers. In other sections of the western grazing district a still less intensive system is followed, the steers not being sold until 3 years of age. However, the tendency is ever toward hurrying the beef animal to the block, and while 4- and 5-year-old steers were once common on the range, but few now reach that age.

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[20] Skinner and Cochel, Ind. Bul. 142.

[21] Information to the authors.

QUESTIONS

1. Into what two phases is beef production largely divided?
2. Define margin and show by example the margin necessary to prevent loss in fattening steers. What factors influence the margin required?
3. Discuss the food requirements of fattening cattle.
4. What are the advantages and disadvantages of fattening 2-year-olds compared with calves or yearlings?
5. How does the degree of finish affect the cost of gains?
6. What factors affect the length of time required to fatten cattle?
7. Discuss the effects of limiting the allowance of concentrates during the fattening period.
8. Wherein do beef-bred steers excel scrubs and dairy-bred steers for beef production?
9. Briefly discuss each of the following: (a) shelter for fattening cattle; (b) the self feeder; (c) water and salt requirements; (d) pigs following steers; (e) cost of fattening.
10. How should beef breeding cows be fed and cared for?
11. Describe various methods of raising beef calves.
12. How should calves be fed for veal?
13. Discuss the feeding of growing beef cattle.
14. What have you learned concerning fattening cattle on pasture?
15. Discuss the production of baby beef; the fattening of yearlings; the fattening of cattle two years old or over.

CHAPTER XXIV

FEEDS FOR BEEF CATTLE

I. Carbonaceous Concentrates

Indian corn.—Of all the concentrates, Indian corn is and will continue to be the great fattening feed for cattle in the United States. It excels not only because of its richness in starch and oil, but also because no other concentrate is so palatable to cattle. Numerous trials have clearly shown, however, that corn is too low in protein, even for fattening animals, and should therefore be fed with legume hay or else with some protein-rich concentrate, such as linseed or cottonseed meal, when only carbonaceous roughages are used. The value of legume hay for supplementing corn is shown in the following table, which summarizes the results of 8 trials, averaging 144 days in length, where corn was fed with carbonaceous roughage, such as timothy hay, prairie hay, corn stover or kafir stover, to one lot of 2- or 3-year-old steers, while corn and clover or alfalfa hay were fed to a second lot.

Legume hay as a supplement to corn

Average ration	Initial weight	Daily gain	Feed for 100 lbs. gain	
			Concentrates	Roughage
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I, unbalanced ration				
Corn, 15.2 lbs. Carbonaceous roughage, 13.0 lbs.....	959	1.7	930	832
Lot II, balanced ration				
Corn, 15.4 lbs. Legume hay, 13.2 lbs.	952	2.3	689	575

While the steers in Lot II, fed corn and legume hay, gained 2.3 lbs. per head daily, those in Lot I, getting the unbalanced ration of corn and carbonaceous roughage, gained only 1.7 lbs., and required 35 per ct. more corn and 44 per ct. more roughage for 100 lbs. gain than the others.

The following table shows clearly the importance of adding some protein-rich concentrate to balance the ration when corn is fed with carbonaceous roughage. This summarizes the results of 4 trials, averaging 132 days, in which one lot of steers was fed only corn and carbonaceous roughage, while linseed meal, cottonseed meal, or gluten feed was added to the ration of the other lot.

Protein-rich concentrates as supplements to corn

	Initial weight	Daily gain	Feed for 100 lbs. gain Concentrates	Feed for 100 lbs. gain Roughage
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I, unbalanced ration				
Corn, 16.3 lbs.				
Carbonaceous roughage, 8.3 lbs.....	995	1.6	1,082	522
Lot II, balanced ration				
Corn, 16.7 lbs.				
Protein-rich concentrate, 2.1 lbs.				
Carbonaceous roughage, 8.6 lbs....	1,002	2.2	862	402

Lot I, fed only corn and carbonaceous roughage, gained but 1.6 lbs. per head daily, while Lot II, receiving 2.1 lbs. of protein-rich concentrates in addition, gained 2.2 lbs. per head daily and required about 20 per ct. less feed per 100 lbs. gain. When the corn allowance is properly balanced, not only is the feeding value of this grain greatly increased with both the cattle and the pigs which follow the steers, but it keeps the animals more healthy, shortens the feeding period, and gives a higher finish than can be secured with unbalanced rations.

Adding a protein-rich concentrate to corn and legume hay.—Whether it will pay to add a nitrogenous concentrate to a ration of corn and legume hay will depend on the relative prices of corn and the other feeds. During the early part of the fattening period steers given all the legume hay they will clean up eat enough of it to balance their ration quite well. Later, when they eat more corn and less hay, the ration becomes too low in protein, and adding a protein-rich concentrate will then cause larger gains. With feeds at usual prices, it ordinarily pays to give at least 2 lbs. of linseed or cottonseed meal per head daily, or an equivalent amount of other protein-rich feeds, when steers are fed corn and clover hay. With alfalfa hay for roughage, there is less advantage in adding protein-rich concentrates, since alfalfa is higher in protein than clover.

Preparation of corn for beef cattle.—The practice of successful stockmen in the corn belt and trials at the experiment stations show that, in general, getting corn to cattle in the simplest manner and with the least preparation and handling is the most economical, when pigs follow the steers to consume any grains which escape mastication. The majority of feeders accordingly feed shock corn, husked or unhusked ear corn, or shelled corn, but few using corn meal or corn-and-cob meal thruout the fattening period. To induce young animals to eat sufficient corn to overcome their tendency to grow rather than to fatten, more preparation is warranted than for older animals. Many skilled feeders seek to "keep the feed better than the cattle," i.e., prepare the feed more as the cattle gain in flesh. Thus, they may start the steers on shock corn, then as they require more concentrates, add snapped corn or ear corn; still later the ear corn is broken or shelled; and toward the close of the fattening period, to tempt them to consume a heavier allowance of grain, corn meal or corn-and-cob meal is employed. Silage from well-matured corn is the most palatable form in which the entire corn plant can be offered to the steer. In addition to the grain in this succulent feed, some corn should be fed, usually in the form of shelled corn or ear corn.

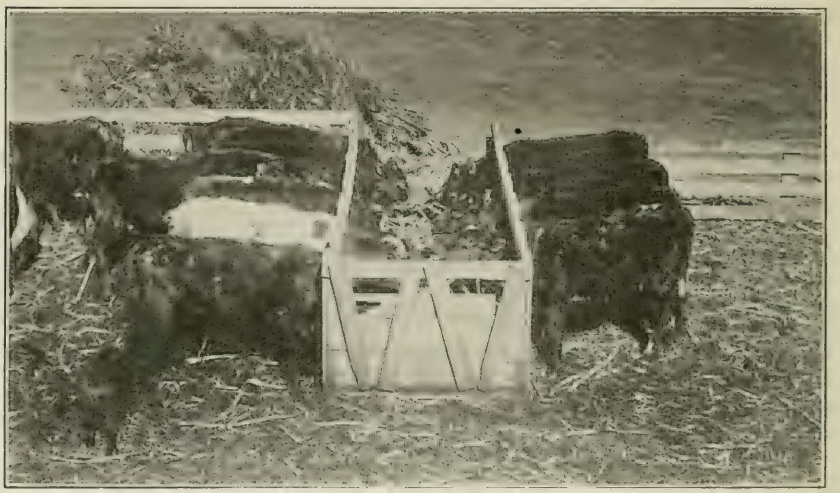

FIG. 86.—FATTENING STEERS EATING SHOCK CORN

Feeding shock corn is an economical practice, especially during the first of the fattening period. Later, more preparation of the corn may be profitable. (From *Successful Farming.*)

Since corn long stored in the crib becomes dry and hard, for summer feeding the grain should be soaked or shelled, or possibly ground.

Other cereals.—In sections of the West where corn does not thrive *barley* is of much importance for fattening cattle. This grain is equal to or but slightly lower than corn in value.

Wheat is seldom fed to cattle except when off grade or unusually low in price. As wheat is less palatable than corn, steers may not eat so much, and hence they may make slightly smaller gains. Otherwise, the feeding value of wheat is as high as that of corn.

Since *oats* are usually high in price compared with other grains, they are seldom used as the chief concentrate for fattening, tho they are well liked by cattle and produce beef of good quality. Oats are excellent for growing cattle, and are also useful for mixing with corn in starting cattle on feed, especially calves being fattened for baby beef.

For the northern part of the Great Plains region *emmer* ranks high as a grain for fattening cattle. Tho in one trial [1] it proved fully equal to corn, its usual value will probably be slightly lower than that of corn.

The *grain sorghums* are of great and increasing importance for beef production thruout the southern portion of the Great Plains region. When fed with alfalfa hay to balance the ration, kafir or milo grain nearly equals corn in feeding value.

The seed of *hog-* or *broom-corn millet,* which is a reliable grain crop on the northern plains, is a satisfactory feed for fattening cattle, being worth about three-fourths as much as corn per 100 lbs.

In the South low grade *rough rice* is sometimes an economical feed for beef production, being worth slightly more than corn.

Since all of these grains are low in protein, they should be fed with legume hay or protein-rich concentrates. All should be ground or crushed for fattening cattle, even when pigs follow, for the grains that escape mastication are too small to be readily recovered by the pigs.

Miscellaneous carbonaceous concentrates.—In the vicinity of western beet-sugar factories thousands of cattle are fattened annually on *wet beet pulp* with alfalfa hay, which admirably supplements this protein-poor feed, and usually with a small allowance of grain in addition. In a trial at the Colorado Station [2] 1 ton of wet beet pulp was equal to 620 lbs. of alfalfa hay or 220 lbs. of ground corn. Animals should be accustomed gradually to the pulp, later getting all they will clean up. Care should be taken that refuse pulp does not accumulate in the troughs and decompose.

In the sugar districts of the South *cane molasses* is an economical carbonaceous concentrate for cattle. When replacing not more than half the corn in a ration, it proved slightly more valuable, pound for pound, than corn in a trial at the Texas Station.[3] In the North, where molasses is relatively high in price, as much as 5 lbs. per head daily is not ordinarily economical, tho a small amount mixed with other feed may be profitable in stimulating the appetite or in getting animals to eat roughage which they would otherwise refuse.

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[1] Wilson, S. D. Bul. 160.

[2] Carlyle and Griffith, Colo. Bul. 102.

[3] Burns, Tex. Bul. 110.

The use of *beet molasses* is greatly increasing in the beet-sugar districts. It is spread over hay or cut straw, either undiluted or thinned with water. Owing to its laxative effect, not more than 4 to 8 lbs. of beet molasses should be fed per head daily to fattening cattle.

II. PROTEIN-RICH CONCENTRATES

Cottonseed meal.—This protein-rich concentrate is the basis of the fattening of beef cattle in the South and is widely used in the northern states to supplement rations deficient in protein. Trials at the Indiana Station,[4] show that about 2.5 lbs. of cottonseed meal daily per 1,000 lbs. live weight is sufficient to balance a ration of shelled corn, corn silage, and oat straw or clover hay. However, in the South, owing to its cheapness cottonseed meal is commonly fed as the sole concentrate, along with cottonseed hulls, corn silage, or other roughage. Since cottonseed meal is poisonous to fattening cattle when fed in excess, they should be accustomed to it gradually and the meal should be mixed with roughage so a greedy steer cannot over eat. Trials at the Tennessee Station[5] show that it rarely pays to feed more than 4 or 5 lbs. during the first of the fattening period, increasing to 6 or 7 lbs. later. Results at the North Carolina Station[6] show that where the market demands highly finished animals it may be profitable to feed as much as 10.5 lbs. per head daily. With cottonseed hulls for roughage, this amount could be fed only 120 to 130 days before poisonous effects began to show, while with corn silage for roughage the fattening could be continued for 30 to 60 days longer without harm. Owing to its protein-rich nature, cottonseed meal tends to produce growth rather than to fatten young steers; hence, 2- or 3-year-olds are best suited for heavy cottonseed meal feeding.

Cold-pressed cottonseed cake is relished by cattle even better than cottonseed meal. In a trial at the Iowa Station[7] 133 lbs. of this cake proved more than equal to 100 lbs. of cottonseed meal.

Linseed meal.—Thruout the northern states linseed meal is widely used as a protein-rich supplement for fattening beef cattle. In trials at the Nebraska Station[8] linseed meal was slightly superior to cottonseed meal as a supplement to corn and prairie hay or corn stover, and produced considerably larger gains than when the ration was supplemented by wheat bran.

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[4] Skinner and King, Ind. Buls. 153, 167, 178.

[5] Willson, Tenn. Bul. 104.

[6] Gray and Curtis, information to the authors.

[7] Kennedy and Robbins, Breeder's Gaz., 58, 1910, p. 303.

[8] Smith, Nebr. Bul. 100.

Wheat bran.—Since wheat bran is lower in protein than linseed or cottonseed meal, a correspondingly larger amount is needed to balance a ration deficient in this nutrient. It is therefore frequently an expensive supplement for fattening cattle. However, this bulky feed is helpful in starting cattle on feed, even tho it is not continued thruout the fattening period.

Soybeans; cowpeas.—These protein-rich seeds are well suited to supplement corn and the other cereals. In trials at the Indiana Station[9] ground soybeans gave good returns when 2.5 to 3.0 lbs. was fed per head daily to supplement a ration of shelled corn, corn silage, and oat straw or clover hay. They were somewhat less satisfactory than cottonseed meal, however, for the steers fed soybeans were more apt to go off feed near the end of the fattening period, due undoubtedly to the large amount of oil the beans contain. With soybean meal, which contains much less oil, this condition would probably not result.

In the southern states it is possible to grow a winter crop of small grain and harvest it in time to plant soybeans, cowpeas, or corn, thus securing 2 crops each year from the same land. At the Tennessee Station[10] in a 7-year trial an acre of winter barley, followed by soybeans grown for grain and stover, produced 508 lbs. of gain when fed to steers, while an acre of barley followed by cowpeas gave 451 lbs. of gain. These returns show the great possibilities of the South for beef production when more than a single crop is grown on the same land each year.

Miscellaneous protein-rich concentrates.—Tho most commonly fed to dairy cows, *gluten feed, dried distillers' grains,* and *dried brewers' grains* are all satisfactory protein-rich concentrates for beef cattle. Whether to use these feeds in place of those already discussed will depend on their relative price.

III. LEGUME HAY AND OTHER DRY ROUGHAGES

Value of legume hay.—The great importance of hay from the legumes in balancing the carbonaceous grains, such as corn, barley, and wheat, has been pointed out earlier in this chapter. Even when a ration of corn and such carbonaceous roughages as timothy hay, prairie hay, or corn fodder is properly supplemented by linseed or cottonseed meal or some other protein-rich concentrate, smaller gains will nearly always be produced than when the ration consists of corn and legume hay. This is shown in the following table, which summarizes the results secured in 4 trials in which 2-year-old 942-lb. steers were fed for periods averaging 158 days:

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[9] Skinner and King, Ind. Buls. 167, 178; information to the authors.

[10] Quereau and Willson, information to the authors.

Legume hay vs. carbonaceous roughage plus protein-rich supplement

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain: Concentrates Lbs.	Feed for 100 lbs. gain: Roughage Lbs.
Lot I			
Legume hay, 9.3 lbs. Corn, 17.9 lbs.	2.3	778	405
Lot II			
Carbonaceous roughage 8.0 lbs. Corn, 16.4 lbs. Supplement, 2.2 lbs.	2.0	916	387

Lot I, fed legume hay and corn, gained on the average 0.3 lb. more per head daily and required 15.1 per ct. less concentrates and about the same amount of roughage as Lot II, fed the equally well-balanced but less palatable ration in which the roughage was prairie hay, timothy hay, or corn stover with a small amount of oat straw. Only when silage, appetizing as well as nutritious, is fed is it possible to provide a ration which will equal one where the roughage is legume hay. Even on farms where much legume hay is raised, considerable carbonaceous roughage, such as corn and sorghum stover, straw, and hay from the grasses, is normally produced. Tho such roughage is inferior to legume hay when fed alone, satisfactory and cheap gains may be secured when it is fed with legume hay as part of the roughage.

Legume hays compared.—Trials at the Indiana Station [11] show that when fed in rations containing ample protein *clover* and *alfalfa hay* have about equal value. However, since alfalfa hay is considerably richer in protein than clover hay, it is more valuable for balancing rations low in this nutrient.

In a trial at the South Dakota Station [12] *sweet clover hay* was practically equal to alfalfa hay for fattening steers. *Cowpea hay*, of much importance in the South, proved fully equal to clover hay in a trial at the Missouri Station.[13] Cowpeas are often sown in corn at the last cultivation and the vines and corn forage grazed after the ear corn has been gathered. Such practice tends to soil improvement as well as cheap meat production.

Corn fodder; corn stover.—Tho there is more waste in feeding corn fodder than corn silage, where the crop can not be ensiled corn fodder is a cheap and satisfactory roughage for fattening cattle, giving especially good results when used with legume hay. When thus fed, bright corn stover may form half the roughage allowance with excellent results. In 2 trials at the Nebraska Station[14] steers fed half corn stover and half alfalfa hay with corn made as large gains as others fed alfalfa hay and corn.

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[11] Skinner and King, Ind. Bul. 178; information to the authors.
[12] Wilson, S. D. Bul. 160.
[13] Waters, Mo. Bul. 76.

Roughages for the plains district.—In the semi-arid districts fodder and stover from both the sweet and the grain sorghums are most useful feeds in beef production, when combined with legume hay or with sufficient nitrogenous concentrates to balance the ration.

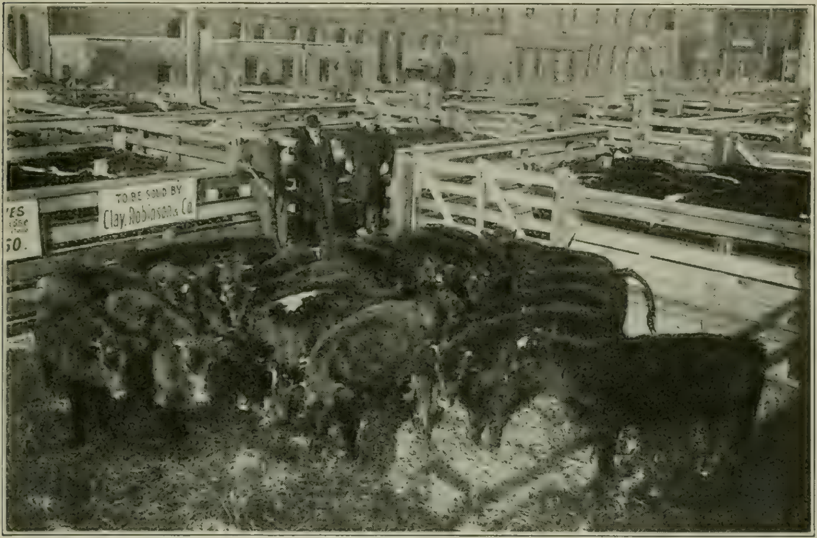

FIG. 87.—THE TYPE OF CALVES FOR BABY BEEF PRODUCTION

Blocky calves of good type and conformation must be selected for baby beef production, as others will not usually reach the desired maturity and finish at this early age.

At the Hays, Kansas, Substation[15] 4 lots of yearling heifers were wintered on 1 lb. of linseed meal, 10 lbs. silage, 2.6 lbs. straw, and either kafir stover, sorghum stover, damaged alfalfa hay, or Sudan hay in addition. Tho the cost of feed and labor was but 5.7 to 6.3 cts. per head daily, the heifers made large enough gains to put them in condition to make good use of pasture the next summer. This trial well shows the possibilities in beef production when wise use is made of by-product roughages that are commonly wasted in grain farming.

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[14] Smith, Nebr. Buls. 90, 93, 100.

[15] Cochel, Kan. Industrialist, May 1, 1915.

Cottonseed hulls.—For many years cottonseed meal and cottonseed hulls formed the standard ration for fattening cattle in the South. On this combination steers made surprisingly good gains. For example, at the Texas Station[16] yearling steers given these feeds made nearly as large gains as others fed corn-and-cob meal and alfalfa hay. Trials at the southern stations have shown, however, that corn silage and cottonseed meal usually make slightly larger and considerably cheaper gains than cottonseed hulls and cottonseed meal.

IV. Succulent Feeds

Silage in beef production.—The use of silage is fast revolutionizing the feeding of beef cattle, just as it has the feeding of milch cows in the leading dairy sections of our country. Breeding cows and stock cattle may be maintained in winter in good condition on silage from well-matured corn or the sorghums, with a limited amount of legume hay or a small allowance of such nitrogenous concentrates as cottonseed or linseed meal. For growing animals this palatable succulence can not be excelled, when fed in proper combination with legume hay or concentrates rich in protein.

On well-balanced rations in which silage is the chief roughage the steer will fatten rapidly and reach a high finish on a moderate allowance of expensive concentrates. By feeding, during the first stages of fattening, only silage and either legume hay or a small allowance of some nitrogenous concentrate to balance the ration, the feed cost of the gains may usually be still further reduced. At first it was thought that silage-fed cattle shrank more in shipment than those finished on dry roughage. Trials have now abundantly shown, however, that if silage is withheld for the last day or two before shipment and dry roughage fed instead, cattle thus fattened will not shrink any more than those receiving no silage.

Corn silage.—Silage from well-matured corn, carrying an abundance of ears and a high proportion of grain, is the best of all silage for beef cattle. Such silage aids materially in reducing the amount of concentrates which need be supplied in addition. To show the good results from feeding corn silage there are summarized in the following table the results of 15 trials where corn silage was added to the already excellent ration of shelled corn, cottonseed or linseed meal, and clover or alfalfa hay. In these trials 2-year-old steers averaging 976 lbs. in weight were fed for an average of 154 days.

[16] Craig, Tex. Bul. 76.

Value of corn silage when added to an already excellent ration

Average ration	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Hay Lbs.	Silage Lbs.	Feed cost of 100 lbs. gain Dollars
Lot I					
Legume hay, 11.2 lbs. Shelled corn, 16.8 lbs. Supplement, 2.6 lbs.	2.42	806	471	...	13.56
Lot II					
Corn silage, 26.4 lbs. Legume hay, 3.2 lbs. Shelled corn, 13.9 lbs. Supplement, 2.7 lbs.	2.44	682	134	1,099	12.28

The steers in Lot II, given a heavy allowance of silage, consumed 26.4 lbs. per head daily and ate 2.9 lbs. less corn and 8.0 lbs. less legume hay than those in Lot I. The silage ration did not produce appreciably larger gains than did legume hay fed as the sole roughage. The chief advantage from feeding silage was the reduction in the cost of the gains when this economical feed was used. In these trials 1 ton of silage saved on the average 226 lbs. of concentrates and 613 lbs. of hay. With concentrates at only $20.00 per ton and legume hay at $14.00 per ton, corn silage was worth $6.55 per ton, considerably more than the cost of production on most farms.

Supplement needed with unlimited silage allowance.—We have seen earlier in this chapter that when steers are fed corn with clover or alfalfa hay as the only roughage, they eat sufficient of such protein-rich hay to balance their ration fairly well. Hence, adding a supplement, such as cottonseed or linseed meal, does not greatly increase the gains. However, if the steers are given all the corn silage they will eat in addition to corn and legume hay, owing to the palatability of the silage, they will then generally eat but 3 to 6 lbs of hay per head daily. Trials at the Indiana Station [17] show that when clover hay is fed, the small amount eaten is not sufficient to balance the ration properly and that about 2.5 lbs. of cottonseed meal or the equivalent of other protein-rich supplements should be fed. Other trials show that there is less advantage in adding a supplement to a ration of alfalfa hay, corn silage and corn, doubtless due to the richness of this hay in protein.[18]

Silage as the sole roughage.—Whether steers fed corn silage only for roughage will make as large gains as those supplied some other dry roughage in addition is important to the cattle feeder. In each of 9 trials at 5 different stations one lot of 2-year-old steers was fed corn and cottonseed or linseed meal with corn silage as the only roughage, while another lot was fed clover or alfalfa hay in addition. The steers fed silage as the sole roughage gained 0.12 lb. less per head daily on the average, but the feed cost was 74 cents less per 100 lbs. of gain than with the steers fed legume hay in addition. However, the steers fed legume hay were slightly better finished and brought on the average 7 cents more per 100 lbs. than the others. In some of the trials they sold for enough more to offset the more expensive gains, so that they returned a greater profit.

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[17] Skinner, Cochel, and King, Ind. Buls. 129, 153, 167, 178.

[18] Bliss and Lee, Nebr. Bul. 151 and information to the authors; Rusk, Ill. Station, Breeder's Gaz., 61, 1912, p. 1041.

In later trials at the Indiana Station[19] it was found that oat straw satisfied the desire of silage-fed steers for dry roughage as well as did clover hay. The gains were no larger on a ration of shelled corn, cottonseed meal (2.5 lbs. daily per 1,000 lbs. live weight), corn silage, and clover hay than when oat straw was substituted for the clover hay. It should be pointed out that these results would not have been secured had not sufficient cottonseed meal been fed to balance the oat straw, corn silage, and corn ration. These extensive trials teach that steers will usually make larger gains and reach a higher finish when fed a small amount of dry roughage in addition to silage. An important fact is that this dry roughage may consist of such cheap material as oat straw, rather than the more expensive legume hay, when a nitrogenous concentrate is fed to balance the ration.

Feeding silage with no shelled corn in addition.—Due to the high prices for corn and other concentrates, several trials have been carried on recently to find whether cattle could not be brought to a satisfactory finish without the use of any grain except that in well-eared corn silage. In 7 trials at corn-belt Stations[20] steers fed no shelled corn, but only 51.3 lbs. corn silage and 3.4 lbs. legume hay per head daily, with 2.9 lbs. cottonseed meal or linseed meal to balance the ration, made the very satisfactory gain of 2.07 lbs. per head daily and reached good marketable finish.

In each trial a second lot was fed a "standard corn-belt ration," including a moderately heavy allowance of shelled corn. These steers ate on the average 13.4 lbs. shelled corn, 2.8 lbs. cottonseed or linseed meal, 31.5 lbs. corn silage, and 2.8 lbs. legume hay. As would be expected, they made considerably larger daily gains, averaging 2.52 lbs. Their feed cost of 100 lbs. gain was, however, $22.47, or $5.34 more than for those fed no shelled corn. The difference in cost of gains was offset to a considerable extent by the fact that much less pork was produced by the pigs following the steers fed no shelled corn.

[19] Skinner and King, Ind. Buls. 163, 167.

[20] Trials by Indiana, Iowa, Missouri, and Wisconsin Stations.

Furthermore, because they were less thoroly fattened, these steers sold for $.91 less per cwt. In 4 of the trials the steers fed shelled corn made larger profits and in 3 trials, the steers fed the economy ration.

These trials well show the possibilities of producing satisfactory beef at a low cost thru feeding but little expensive concentrates. In deciding upon which system of beef production to follow, the chief factor is the difference there will probably be between the price of thoroly fattened steers and those in only moderate flesh. When it is probable that prime steers will not command a considerable premium, it is the safest plan to feed but little concentrates. (See Page 296.)

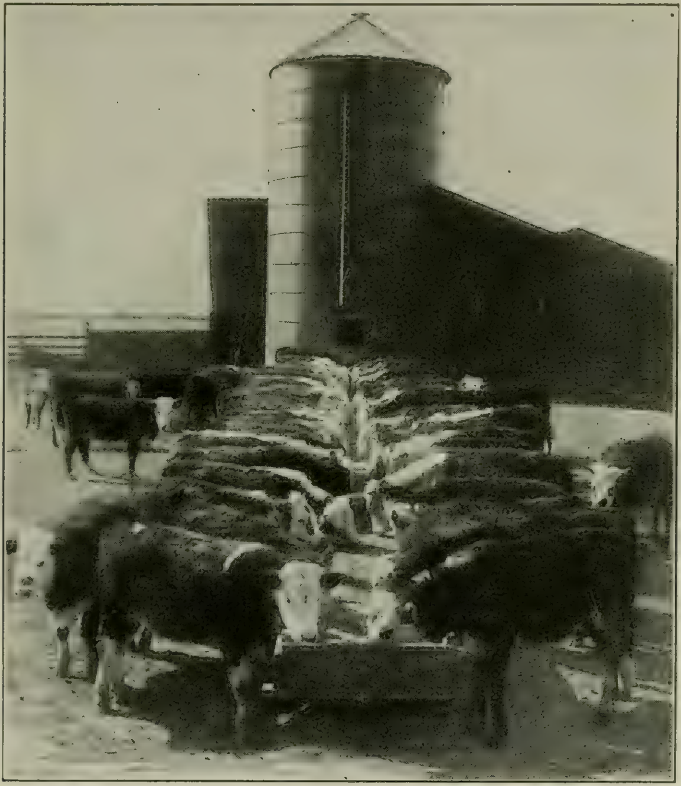

FIG. 88.—THE USE OF SILAGE IS REVOLUTIONIZING BEEF MAKING

Baby beeves fattening on kafir silage and cottonseed meal in a Texas feed lot. (From *The Southwest Trail*, Rock Island Lines.)

Corn silage vs. shock corn.—The superiority of corn silage over shock corn or corn fodder is well shown in a trial at the Illinois

Station [21] in which growing beef calves were fed either corn silage or shock corn from the same field, with 2 lbs. of oats and 4.0 to 4.6 lbs. of mixed hay per head daily. The silage-fed calves made slightly larger gains, but the chief advantage lay in the fact that more of the shock corn was wasted and hence the corn from a much larger area was needed to feed the steers getting shock corn than for those fed silage. Taking everything into consideration, the corn silage from an acre was worth 30 per ct. more than the shock corn from the same area. In a trial at the Missouri Station [22] with fattening steers the difference was still greater, silage being worth over 50 per ct. more than the shock corn from the same area.

Silage from other crops.—In silage from the sorghums the feeder of the semi-arid regions has an admirable substitute for corn silage. In 3 trials at the Kansas Station [23] steer calves were wintered on about 26 lbs. of corn, kafir, or sweet sorghum silage per head daily, with 1 lb. of cottonseed meal or 1 lb. of corn and 1 lb. of linseed meal in addition. All lots made satisfactory gains and the several kinds of silage had about the same feeding value. The feeder in this section should grow for silage whichever crop will yield the greatest tonnage.

The southern beef producer has available not only corn silage but also silage from sweet sorghum, corn or sorghum grown with cowpeas or soybeans, and, in the Gulf region, Japanese cane.

Roots.—Wherever corn or the sorghums thrive, silage from these crops provides cheaper succulence than do roots. In northern districts where root crops flourish but where corn will not mature sufficiently for silage, roots are a valuable feed for beef cattle. When only 6 to 9 lbs. was fed per head daily, roots proved fully equal, pound for pound, to good corn silage in a trial at the South Dakota Station.[24] At the Ontario Agricultural College,[25] where larger allowances of roots were fed, silage had a somewhat higher value per 100 lbs. than roots, due to the larger percentage of dry matter it contains.

In Great Britain roots are extensively used for fattening cattle, from 35 to as much as 150 lbs. per head daily being fed along with 6 to 7 lbs. protein-rich concentrates, such as linseed meal, cottonseed meal, dried brewers' and distillers' grains, and peanut cake. The roots are commonly pulped and mixed with the concentrates and hay or straw before feeding. By this means large amounts of cheap roughages are utilized. On this small allowance of concentrates and heavy allowance of roots the cattle make excellent gains and reach a satisfactory finish. With the high prices for concentrates now prevailing in this country, our feeders may wisely adopt a similar system of beef production, employing silage from corn and the sorghums instead of the roots which are the basis of English feeding.

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[21] Mumford, Ill. Bul. 73.
[22] Allison, Mo. Bul. 112.
[23] Cochel, Kan. Bul. 198; Kan. Industrialist, Apr. 18, 1914, May 1, 1915.
[24] Wilson, S. D. Bul. 137.
[25] Day, Ont. Agr. Col., Rpts. 1901, 1902.

QUESTIONS

1. What do feeding experiments show as to the advantage of supplementing corn with legume hay or protein-rich concentrates for fattening cattle?
2. Discuss the preparation of corn for beef cattle.
3. How do barley, wheat, oats, the grain sorghums, millet, and rough rice compare with corn in value for fattening cattle?
4. Would you use cane or beet molasses in fattening cattle in your locality?
5. Discuss the use of cottonseed meal for fattening cattle, especially the amounts to be fed under various conditions.
6. State the value of other protein-rich concentrates important in beef production.
7. How does a ration of corn and legume hay compare in value with one of corn, carbonaceous hay, and a protein-rich supplement?
8. Discuss the use of corn fodder, corn stover, and cottonseed hulls for cattle.
9. What are the advantages of feeding silage to fattening cattle?
10. What have trials shown concerning (a) the need of a supplement when corn silage is fed, (b) the use of silage as the sole roughage?
11. How does an acre of cured corn forage compare in value with the silage from the same area?
12. What other crops furnish valuable silage for beef cattle?
13. Tell how roots are used for feeding cattle in Great Britain.
14. Using feeds available in your section, compute the most economical ration according to the Modified Wolff-Lehmann Standard for fattening 2-year-old steers averaging 1,100 lbs. in weight. Follow the method given in Chapter VIII and compute the ration for the second 50–60 days of the fattening period.

CHAPTER XXV

FEEDING AND CARE OF SHEEP

I. GENERAL PROBLEMS IN SHEEP HUSBANDRY

The sheep is the plant scavenger of the farm. Because of its dainty manner of nibbling herbage, we might suppose that its likes were few and dislikes many, yet no domestic animal is capable of living on more kinds of food. Grasses, shrubs, roots, and cereal grains, leaves, bark, and in times of scarcity fish and meat, all serve as food for this wonderfully adaptive animal. While horses and cattle eat only about half the plants considered weeds, less than one-tenth of them are refused by sheep. They even prefer some weeds, when yet succulent, to the common grasses. Sheep graze more closely than other stock, and if many are confined to one field every green thing is at length consumed. When closely pastured on cut-over timber lands they derive much nourishment from the leaves, bark, and twigs, destroying the brush nearly as effectively as goats. The feces of the sheep show the finest grinding of any of the farm animals, and as they relish

FIG. 89.—A PROFIT-MAKING FLOCK CLEANING UP THE FARM LANE

On many farms where most of the income is derived from other sources a flock of sheep would bring additional profits, since they consume much food which would otherwise be wasted. (From *Breeder's Gazette.*)

most weed seeds this further fits them as weed destroyers. As sheep graze, their droppings are distributed more uniformly than with other stock. At nightfall they instinctively seek the higher, usually poorer, land and thus leave their droppings where most needed. Thru increasing the fertility of the pastures it grazes, this animal has won the title of "The Golden Hoof."

Only a relatively small investment is necessary to start in sheep husbandry, since the foundation animals cost but little and the flock increases rapidly. Sheep require neither expensive barns nor implements and only a minimum of care and attention during the busy summer season. In wool and in the flesh of her off-spring, the ewe gives double returns each year. With fair prices, the wool pays for her maintenance, leaving as profit all income from the lamb or lambs, after deducting the small cost of the additional feed and care they require. Returns come quickly, for lambs may be marketed 8 or 9 months after the ewes are bred. While surpassed by the pig in economy of meat production, the lamb requires less feed per pound of product than the steer. Because sheep readily consume food which would otherwise be wasted, a flock will prove profitable on many farms where most of the income is derived from other sources. On rough or hilly land that cannot be economically tilled sheep may often be the main live stock of the farm. Tho the cost of maintaining them may be lowered thru their utilization of feed that would otherwise be wasted, one must not expect profitable production from such feed alone.

Types of sheep.—The original fine-wool or Merino sheep were developed primarily for the production of wool and have bodies which, like that of the dairy cow, are inclined to be angular in form. At the other extreme we have the mutton sheep, comprising the middle- and long-wooled breeds, which were developed in Great Britain primarily for the production of meat, with wool secondary. In shape of body these breeds resemble the beef breeds of cattle, being blocky and compact. During recent years the Delaine-Merinos and the Rambouillets have been developed from the original Spanish Merinos with the object of securing a fine-wool sheep that would furnish more mutton. These are of dual-purpose type, between the two extremes in form of body.

Size of flock.—In the grazing districts of the West thousands of sheep carrying more or less Merino blood are held in single bands where the range furnishes sufficient feed, and tens of thousands may be successfully fed together, as is still done with range sheep which are brought to feeding points in the western states and in the Mississippi valley.

In the humid regions, however, two hundred sheep of the mutton breeds are as many as can usually be successfully managed in one flock, for when the farm is heavily stocked with sheep, the troubles from stomach worms and other parasites are greatly increased. The beginner had best begin with a flock of 25, increasing the number as experience grows.

Fattening sheep of different ages.—The following table, giving the results of an 88-day trial at the Montana Station,[1] shows that lambs make much more economical gains than do older sheep:

Fattening range sheep of different ages

Age when fed	Average ration		Av. wt. at beginning	Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
	Barley	Clover hay				Barley	Clover hay
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lambs	0.7	2.1	63	0.27	23.7	253	763
One-year-old wethers	0.7	3.8	95	0.27	23.5	256	1,413
Two-year-old wethers	0.7	4.1	116	0.28	24.3	248	1,469
Aged ewes	0.7	2.3	92	0.18	15.6	387	1,320

It will be observed that all lots, except the aged ewes, made practically the same daily and total gains. All were fed the same amount of grain, but the lambs ate only about half as much hay as the yearlings or 2-year-olds. Hence, the gains of the lambs were much more economical. In other trials at the same Station, lambs made not only more economical but also more rapid gains than yearling wethers.

Not only do lambs make cheaper gains, but they also bring a higher price per 100 lbs., due to the fact that their tender, juicy, well-flavored meat is popular with Americans. Moreover, when the animals are fattened as lambs the money invested is sooner returned, and there is less risk from death and accident. Therefore, but few lambs are held over to be fattened as yearlings or 2-year-olds. Owing to their tendency to grow, lambs fatten more slowly than do mature wethers. Since they are making not only fat but also lean meat, the ration should be somewhat narrower; that is, contain more protein, than is needed for fattening mature sheep. However, a ration which is too narrow will unduly stimulate growth, and not fatten them properly. The food requirements of fattening lambs of various weights are given in Appendix Table V, as are also feeding standards for maintaining mature sheep and for breeding ewes.

Shelter and exercise.—Above every other animal on the farm, the sheep should be kept dry as to both coat and feet to avoid disease. With dry winter quarters sheep will stand severe cold without injury. One thickness of matched boards makes the barn or shed where sheep are confined sufficiently warm in the northern states, except for winter lambs. Ample ventilation is of great importance, but drafts must be avoided. On the western plains, it is even more necessary to protect sheep from cold winds than from rain. Sunshine, good drainage, and conveniences for feeding are the other requisites of a good sheep barn.

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[1] Shaw, Mont. Bul. 35; see also Mont. Buls. 47, 59.

In late spring and early summer the flock should be sheltered from cold rains, if possible, for exposure is dangerous, especially to young lambs. In summer, if there is no natural shade in the pastures, the flock should have access to a darkened but well-ventilated shed. A fringed curtain thru which the sheep may pass will keep back flies from this retreat. In winter a dry yard, having a sunny exposure and provided with a well-bedded, comfortable shed opening to the east or south, is ideal for fattening lambs and sheep, except in the extreme northern states. Here, lambs sheltered in a well-ventilated barn and turned out daily for exercise will make slightly cheaper gains. In the arid regions, protection from driving winds and sandstorms is all that is essential. Even in the South the sheep should be protected from winter rains.

For the breeding flock abundant exercise thruout the year is essential. Fattening animals, however, make better gains if allowed only moderate exercise.

Water; salt.—Opinions as to the water requirements of sheep vary more than with any other domestic animal. In countries with heavy dews and ample succulent feed in summer, and where roots are largely used in winter, water may possibly be denied sheep, but ordinarily it is a necessity. Because of the danger of infestation with internal parasites, drinking from stagnant pools must be avoided. On the arid ranges of the Southwest, when grazing on certain succulent plants like singed cacti, sheep sometimes go two months without water. The wise shepherd will under all usual conditions supply his sheep with water daily, providing from 1 to 6 quarts, according to feed and weather. Ewes suckling lambs, and fattening sheep require more water than those being simply carried thru the winter.

Sheep especially require salt, which should be available at all times, for an irregular supply induces scouring. In winter it may be given in a trough used only for this purpose. In summer salt may be rendered doubly useful by scattering it on sprouts growing about stumps, on brush patches, or over noxious weeds.

Grinding grain; cutting or grinding hay.—Of all farm animals, the sheep is best able to do its own grinding, and with few exceptions only whole grain should be furnished. The common saying of feeders, "a sheep which cannot grind its own grain is not worth feeding," is true. Valuable breeding sheep with poor teeth may be continued in usefulness if given ground grain. Small, hard grains, such as wheat, bald barley, and millet, should be ground, or better, crushed for sheep.

Cutting or chopping alfalfa hay of ordinary quality reasonably fine, may save 15 to 25 per ct. of the hay.[2] When hay is cheap, this saving is too small to be profitable, but with present prices many large feeders are finding such preparation good economy. The lower the quality of the hay, the greater is the saving thru cutting or grinding.

Self feeders; feed racks.—To save time and labor some feeders place sufficient grain for a week or more in a self feeder, and allow fattening lambs or sheep to eat at will. This is ordinarily an expensive practice, since more feed is required for 100 lbs. gain. Usually it is necessary to feed by hand the first 5 or 6 weeks of the feeding period, to accustom the sheep to a full feed of grain before them all the time. In some districts of the West the practice is sometimes followed of starting fattening lambs at once on self feeders filled with linseed meal and gradually mixing in shelled corn, until at the end of 2 weeks the lambs are receiving a mixture of 4 parts corn and 1 of linseed meal. In trials at the Nebraska Station this practice has proven less profitable than hand feeding.[3] Numerous investigations show that the death rate of lambs is usually higher when self feeders are used, except with a bulky feed like the lighter grades of wheat screenings. Morton[4] reports that under Colorado conditions, when lambs are fattened in the open, self-feed hay racks, accommodating 4 lambs per foot, 2 on a side, saved sufficient hay, compared with feeding it on the ground outside the pens, to pay their cost in 3 seasons.

Grain and roughage should be fed separately to sheep. If sheep are fed in close quarters the hay should be supplied daily, since they dislike provender that has been "blown on," as shepherds say. In feeding sheep in open lots, as is done thruout the West, racks sufficiently large to hold roughage for several days are often used. Grain troughs should have a wide, flat bottom, forcing the sheep to eat slowly. Fifteen inches of linear trough space should be provided for each animal.

II. Hints on Feeding and Caring for Sheep

Feed and care of ewes.—Experienced shepherds have found that ewes which are gaining rapidly in flesh at breeding time are more apt to produce twins or triplets than if they are poor in flesh. Having more than one lamb per ewe is most profitable, except on the western ranges, where but little attention can be given the individual ewes. Accordingly, with the farm flock it is advisable to ''flush'' the ewes for 2 or 3 weeks before they are bred; i.e., to supply an abundance of palatable, nutritious feed, such as rape, cabbage, good clover pasture, or grain. This is especially needed if the ewes have run down in flesh during summer thru suckling their lambs.

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[2] Morton, Colo. Buls. 151, 187.

[3] Gramlich, Nebr. Buls. 170, 173.

[4] Colo. Bul. 187.

Breeding ewes which are in good condition in the fall need little or no grain in winter until about a month before lambing, if given all the bright legume hay they will eat with an allowance of silage or roots in addition. At that time, or sooner if they are not in thrifty, vigorous condition, they should be given a limited amount of concentrates, up to 0.5 per head daily, with good roughage. When legume hay is fed, a considerable part of the concentrates may be corn, barley, oats, kafir, and other carbonaceous grains. Mixed with these should be such feeds as wheat bran, linseed meal, and dried brewers' grains.

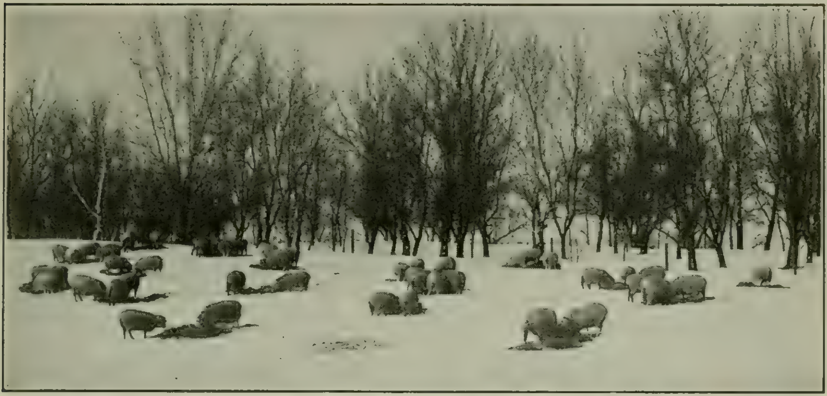

Fig. 90.—Exercise Is Essential for the Ewe Flock

In winter the ewes may be forced to exercise by scattering roughage over a nearby field. (From Kleinheinz, Wisconsin Station.)

The best roughages for ewes are the legume hays—clover, alfalfa, cowpeas, and vetch—all of which are palatable and rich in protein, and help ward off constipation, a serious danger to the ewe. Other roughages which are useful to feed with legume hay are bright corn fodder or corn stover, oat hay, prairie hay, and oat straw. Timothy hay is too constipating for ewes. Two to 3 lbs. of corn silage or chopped roots per head daily aids greatly in keeping the ewes thrifty. Too much succulent feed may produce weak, flabby lambs. One-half pound of grain, 3 lbs. of legume hay and 2 to 3 lbs. of roots or silage daily should keep ewes of average size in good condition during the winter.

To insure a crop of strong, healthy lambs, exercise for the ewes in winter is essential. They should have access to a dry, sunny yard, well protected from wind and storm, and on all fair days should be forced to exercise by scattering roughage over a nearby field. When the snow is deep, paths should be broken out with snow plow or stone boat. On stormy days the sheep should remain indoors.

To avoid udder troubles, ewes should be given but little grain for two or three days after lambing, and the allowance gradually increased with the demand for more milk by the lamb. With good roughage not over 2 lbs. of concentrates per ewe daily is necessary. Legume hay and succulent feeds are essential at this time, and more silage or roots may be safely fed than before lambing. After being turned to pasture the ewes need no additional feed, if grazing is good.

The ram.—For a good lamb crop, it is essential that the ram be kept in thrifty, vigorous condition. He needs no grain while on good pasture during summer, but beginning at least a month before breeding time some concentrates should be fed. During the breeding season he should be fed such muscle-forming foods as bran, oats, peas, and oil meal, and not be allowed to run down thru insufficient feed or over use. On the other hand, he should never become fat.

In winter the ram may be kept thrifty on a daily allowance of 0.5 to 1.0 lb. of concentrates, with good roughage. Some succulent food is desirable but mangels and sugar beets should be avoided. Lack of exercise injures the ram's breeding powers. Ram lambs need liberal rations of muscle-building foods, but should be given little fat-forming food.

Lambing time.—In about 147 days after the ewes are bred the lambs may be expected. During 24 years, at the Wisconsin Station[5] the average birth weight of lambs of the mutton breeds was 9.1 to 10.6 lbs. for single lambs, 7.7 to 8.5 lbs. each for twins, and 5.5 to 8.2 for triplets. On the average, 161 lambs were yeaned each year per 100 ewes during this period, a result which can be secured only with good feed and excellent care.

The shepherd should always be close at hand during lambing time to assist the ewes or any weak lambs. It is wise to provide lambing pens for the ewes and their newly born lambs. Here each ewe and her young may remain for a couple of days until they are wonted to each other and the lambs are strong enough to look out for themselves among the flock.

Raising the lambs.—After about 2 weeks the lambs begin to show a desire for feed in addition to their dam's milk and will be found nibbling at the feed trough beside their mothers. They should now be provided with both grain and hay at one end or corner of the barn which is fenced off by means of a "lamb creep" thru which only the lambs can enter. This may be made of two 1x6-inch boards, to which are nailed 1x4-inch vertical strips about 3 feet long, spaced just far enough apart to allow the lambs to pass thru but keep the ewes back. Within this enclosure there should be a low, shallow trough with an obstruction lengthwise over the top to prevent the lambs from jumping into it. In this trough should be sprinkled a mixture of such feeds as ground oats, wheat bran, corn meal, and linseed meal. Fine alfalfa or second-crop clover hay is also excellent for young lambs. The feed should never be allowed to grow stale. Fresh, clean water should also be provided.

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[5] Kleinheinz, Wis. Rpts. 1902, 1907, and information to the authors.

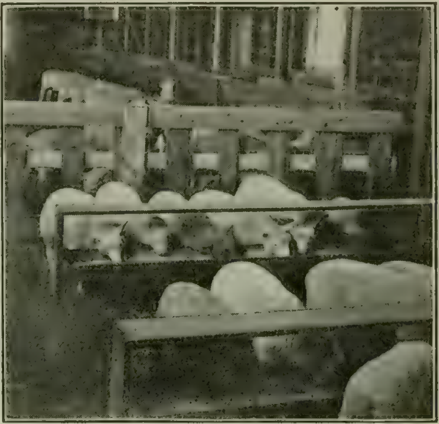

Fig. 91.—Meal time for the lambs. Notice the lamb creep separating the ewes in the background from the lambs. (From Kleinheinz, Sheep Management, Breeds, and Judging.)

The change to pasture should be gradual, the ewes and lambs being turned on grass for only a few hours at first and then brought back to shelter, where more feed awaits them. It is usually best to feed the lambs concentrates in addition to pasture and the milk they get from their dams. This may be provided by means of a "lamb-creep" at some convenient point.

At 4 to 5 months of age the lambs should be weaned, for their own good and also to give their mothers a rest before another breeding season. If possible, advantage should be taken of a cool spell and the lambs and their dams should be so separated that neither can hear the bleating of the other. For a few days the ewes should be kept on short pasture or dry feed to reduce their milk flow, and attention must be given their udders. The lambs should be put on the best pasture, such as clover or rape, and given a liberal supply of grain.

After weaning, lambs that are to be marketed early may profitably be fed grain, but those to be fattened in winter and the ewe lambs to be retained for the breeding flock need no grain when the grazing is good. Ram lambs should be given grain in fall to insure good development.

Stomach worms.—East of the Mississippi stomach worms are a serious menace to sheep raising, lambs being especially liable to attack. The eggs of the parasite, which are scattered over the pastures in the droppings of the sheep, soon hatch and the worms may be swallowed by the sheep while grazing. Fields on which no cattle, sheep, or goats have grazed for a year, and those that have been plowed and cultivated since sheep grazed on them, are usually free from worms. Old permanent pastures are apt to be infested, as are stagnant water pools.

Trouble from stomach worms may be avoided by changing sheep and lambs to fresh pasture frequently. It is especially necessary to place the lambs on fresh, clean pasture when they are taken from their dams at weaning time. Where sheep are suffering from the worms, various drenches may be used. The most common one is 1 tablespoonful of gasoline for lambs and 1½ tablespoonfuls for large, older sheep, mixed with one-third pint of fresh cow's milk and 1 tablespoonful of raw linseed oil. The treatment should be repeated each morning for three days, the sheep getting no feed over night.

Fattening lambs in the fall.—Finishing lambs for the market in the fall is common with farmers who raise their own lambs and with many who buy feeder lambs from the western ranges. Until cold weather the lambs may be grazed on rape, stubble fields, or other pasture, being fed grain in addition. Sometimes the lambs are shifted to fields of standing corn after the stubble fields are well gleaned. Here they feed on the lower leaves of the corn stalks and on rape or turnips sown at the last cultivation, finally eating more or less of the corn on the ears. Thrifty lambs placed on feed in the early fall should be ready for sale by December or early in January, a season when there is usually a scarcity of good lambs on the market, since the grass-fed lambs have been marketed and those in winter feed lots are not yet finished.

Fattening lambs in winter.—Most western lambs are fattened for market in winter. As they usually have never had grain, they must be started on feed slowly lest some be injured or even killed. At first they should be given all the roughage they will eat, with a little grain —not over 0.1 lb. per head daily—sprinkled thinly in the troughs. The allowance may be gradually increased until in 2 months or less they are on full feed.

Farm-raised lambs take grain more readily, and in some cases but 3 or 4 weeks need intervene between placing the lambs on feed and full feeding. In all cases, before sheep are admitted to the fattening pens they should be examined by an experienced shepherd, and if any evidence of scab, lice, or ticks is found, the flock should be dipped most thoroly.

With lambs which have received no grain on pasture, the feeding period should last 12 to 14 weeks, depending on their condition and the rapidity with which they fatten. For a 100-day feeding period the gains should be 25 to 30 lbs. per head. This gain added to a lamb weighing originally 55 to 65 lbs. brings it to the size desired by the market, for the demand is now for plump lambs weighing only 80 to 90 lbs., or even less if from the western ranges. As soon as the lambs are "ripe," or when the back and the region about the tail are well covered with fat, they should be sold, for further gains can not be made at a profit.

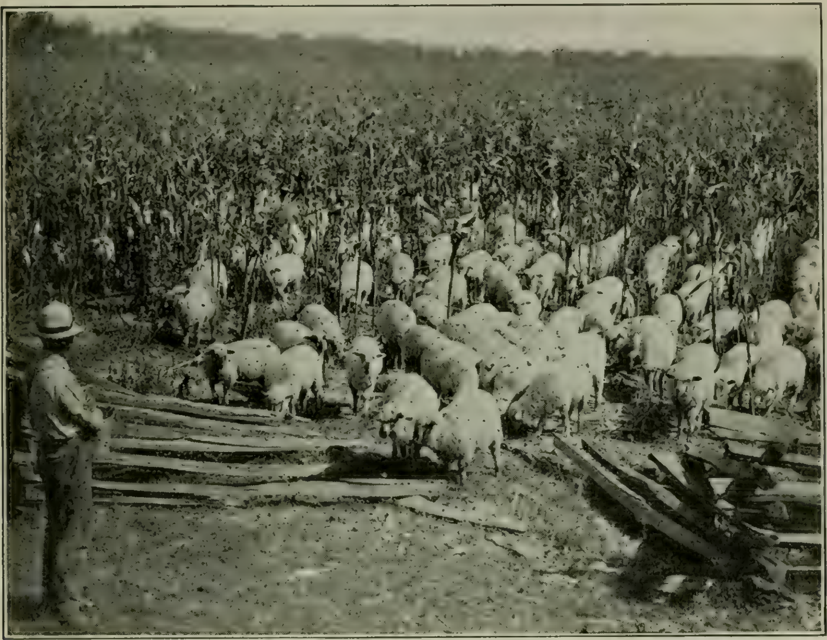

FIG. 92.—LAMBS FATTENING IN A FIELD OF CORN AND SOYBEANS

Many farmers find it profitable to fatten lambs in the fall on rape, stubble fields, or standing corn. (From *Breeder's Gazette.*)

Sheep feeders do not begin operations at an early hour in winter, preferring not to disturb the animals until after daybreak. Usually grain is first given, followed by hay and water. The trough in which grain is fed should be kept clean at all times, and sufficient space should be provided so each animal may get its share of grain. Regularity and quiet are of especial importance with fattening lambs and sheep.

Fattening in the corn belt and eastward.—In the corn belt and eastward corn and clover or alfalfa hay are commonly used for fattening lambs, with or without cottonseed meal, linseed meal, or wheat bran. Thruout these districts it is usually most profitable to feed the lambs all the grain they will eat after being brought to full feed. Feeders frequently fatten two lots of lambs the same season, marketing the first in January and the second late in spring. Should the weather grow warm before the lambs are finished, shearing results in better gains. Shelter is required to protect the lambs from winter storms. In the corn belt lambs are commonly allowed the freedom of small yards with an open shed or barn adjacent, while in the East a more forced system of fattening is often followed, the lambs never being turned out from the barn or shed for exercise. In this system the grain troughs are protected by vertical slats in such a manner that there is just room for a lamb to feed in each opening, and only one space is provided for each lamb. The lambs are brought to full feed as quickly as possible, and they are then given all the grain they will clean up. With such heavy feeding and scant exercise, care must be taken to keep the lambs quiet, and a feeding space must be closed up whenever a lamb is removed from the pen, for excitement and overeating cause heavy losses from apoplexy.

Fattening in the West.—In the West, where hay is cheap compared with grain, the allowance of grain is often restricted thruout the fattening period so the lambs will eat more hay. Sometimes hay only is fed, but sheep cannot be made fat enough for the large markets on hay alone. Hence western feeders often give only hay during the first part of the fattening period and later add grain to finish the lambs and harden the flesh. With a light allowance of grain, the lambs must, of course, be fed longer to reach a given finish than when they are given all the grain they will eat. The feeds most commonly used in the West are corn, barley, or other cereals, with alfalfa hay, and with wet beet pulp in the vicinity of the beet-sugar factories.

In large feeding plants the corral, or enclosure, is commonly divided into 2 rows of lots with a lane between, each lot accommodating from 400 to 500 lambs. No shelter is provided, but windbreaks are desirable. The hay is usually fed in the lanes, 12 to 14 feet wide, extending between the lots. The low fences bordering the lanes have a 7 or 8 inch space between the first and second boards, thru which the lambs feed on the hay. About 1 running foot of lane fencing and feed troughs is allowed each sheep. The hay from the stacks is hauled down the lanes and piled along the fences, being pushed up to them 2 or 3 times a day as it is eaten away.

All lots are provided with flat-bottomed troughs for feeding grain. There is an extra or vacant lot at one end of each row of lots, likewise provided with troughs. At feeding time grain is placed in the troughs of this extra lot and the lambs from the adjoining lot are turned in. As soon as a lot is vacated, grain is put in the troughs of this lot, and the lambs enter from the next lot, and so on. At the next meal feeding begins by using the vacant lot at the other end of the row, reversing the process. The feeding yards are usually located on streams or ditches which supply running water. Those on high ground have watering troughs into which the water is pumped. Salt is liberally furnished in troughs.

Feeding small bands.—Fattening great numbers of lambs at a single point reached its height years ago when corn and wheat screenings ruled low in price, and the large operator had little competition from the ranchman and farmer in finishing range lambs for the market. Now the price of feed has increased, and the fattening of range lambs in smaller bands has rapidly developed in the western states, in the corn belt, and farther eastward. Most fortunately for a conservative agriculture, the large operator, who often receives no benefit from the great accumulation of rich manure in the feed lot, cannot compete with the farmer who fattens one or more carloads of lambs and uses the manure for enriching his land. Prudent farmers rightly hold that enough fertility is returned to their land thru the feed lot to pay the entire labor cost of feeding. As sheep and lamb fattening on range and farm increases, the gradual decline of the old feed lot is assured.

Yield of dressed carcasses; shrinkage.—The slaughter tests at the various stations show that lambs and yearlings dress from 48 to 57 per ct., depending on how completely they are fattened. Shaw[6] states that fattened lambs weighing over 100 lbs., when 4 days in transit, will shrink 7 to 8 lbs. per head; 1-year-old wethers weighing about 120 lbs., approximately 10 lbs.; and aged wethers and ewes about 12 lbs. per head. When sheep are marketed off pasture, especially rape, excessive shrinkage from scouring may be prevented by giving only dry feed for a day or more before shipping. The concentrate allowance should be decreased for the same reason, and oats are the best grain for sheep in transit.

Hot house lambs.—During recent years an increasing demand has developed for winter or "hot house" lambs. The term "hot house" does not imply that the lambs are raised in artificially heated quarters, but is used because they are produced out of season, as are the vegetable products of hot houses. The demand for winter lambs comes from the last of December to Easter, and the ewes must accordingly be bred in the spring instead of in the fall, as usual Dorset, Tunis, and Merino or Rambouillet ewes are commonly used for raising winter lambs, for the other breeds rarely breed at the right season. After lambing, the ewes are fed so as to yield an abundant flow of milk, and the lambs are early taught to eat grain and forced rapidly on such feeds as corn, oats, bran, and linseed meal, with good legume hay and preferably either roots or silage in addition. Thus forced, the best lambs weigh 50 to 60 lbs. at 10 to 12 weeks, when they are ready for market. Winter lambs must be fat, for the condition of the carcass is more important than its size. To be profitable, they must sell for not less than $5 per head, and the best ones sometimes bring $12. This specialty can be conducted with profit only by experts who have nearby markets that will pay the high prices such products must command.

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[6] Management and Feeding of Sheep, p. 365.

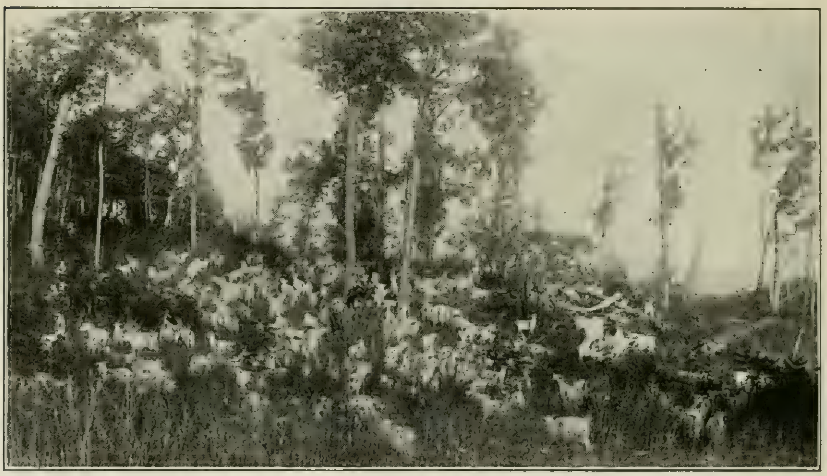

FIG. 93.—ANGORA GOATS CLEARING LAND OF BRUSH

Goats are especially fond of the leaves and twigs of brush and if pastured closely enough will effectively kill the brush.

Spring lambs.—A less intensive system than the preceding is the production of spring lambs, which are dropped from January to March and are usually marketed in May and June, weighing 65 to 90 lbs., at a time of the year when there is a good demand. Raising spring lambs is especially profitable in Tennessee, Kentucky, Virginia, and states to the southward, for here the ewes may be largely maintained on pasture thruout the year, thus greatly lowering the feed bill.

Goats.—The raising of Angora goats for their mohair is an important industry in certain districts of the United States, especially Texas, New Mexico, Arizona, Oregon, and California. In the western states the goats graze upon rough land, utilizing browse which even sheep would refuse. In the cut-over districts of the North, Angora goats are useful in clearing land of brush at a low expense.

In Europe the milch goat is of importance as a milk producing animal. By their habits they are peculiarly adapted to the needs of the peasants, or poorer classes of these countries, and have hence been appropriately termed "the poor man's cow." While they have not yet become numerous in this country, milch goats are receiving increasing attention in some districts, as they are especially well suited to families living in small towns and in the suburbs of large cities. Often they can secure much of their feed by grazing in waste places, such as vacant lots and on rocky hillsides.

In general the same feeds which are used for dairy cows are suitable for milch does. From 6 to 8 goats can be kept upon the feed required for a cow. A good milch goat should yield 2 quarts or more of milk a day and continue in milk for 7 to 10 months. In the winter such a ration as 2 lbs. alfalfa or clover hay, 1.5 lbs. silage or roots, and from 1 to 2 lbs. of concentrates will be satisfactory for milking does. Often the use of refuse from the kitchen will considerably reduce the feed bill. The general principles of feeding and care which have been presented for sheep also apply to goats.

QUESTIONS

1. Discuss the place of sheep on the farm, the types of sheep, and the size of the flock.
2. Why are most sheep fattened as lambs?
3. What are the requirements of sheep for shelter, exercise, water, and salt?
4. Discuss the preparation of feed for sheep and the use of self feeders.
5. How would you feed and care for breeding ewes?
6. State how rams should be fed.
7. Tell briefly of the feed and care of lambs from birth.
8. Describe the method of preventing trouble from stomach worms and of the treatment.
9. Outline the method of fattening lambs (a) in the fall, (b) in the winter.
10. How are lambs fattened (a) in the corn belt, (b) in the eastern states, (c) in the West?
11. What is the shrinkage of sheep in transit and the usual dressing percentage?
12. Discuss the production of (a) hot house lambs; (b) spring lambs.
13. What is the importance of the two types of goats in this country?

CHAPTER XXVI

FEEDS FOR SHEEP

I. CONCENTRATES FOR SHEEP

In the following paragraphs, which discuss the value of various feeds for sheep, especially for fattening animals, it will be noted that nearly all the trials reviewed were with lambs. This is due to the facts pointed out in the preceding chapter, that lambs make better use of their feed than older animals and that their flesh is in greater demand.

Indian corn.—Corn, the best single grain for fattening sheep, is the cereal most commonly used in this country as far west as Colorado, beyond which barley and wheat are more generally fed. Since legume hay, rich in protein, admirably supplements corn, the combination of corn and clover or alfalfa hay has become a standard ration for fattening sheep over a large district. In this chapter other rations will, where possible, be compared with this successful combination. To show the possibilities of these feeds, below are averaged the results from 8 stations with 26 lots, including 527 lambs, which were fed an unlimited allowance of shelled corn and either clover or alfalfa hay, for periods averaging 90 days. The results are also given from 4 stations at which 17 lots, including 1,180 lambs, were fed a limited allowance of shelled corn (from 0.7 to 1.1 lbs. per head daily) with the same roughages, in trials averaging 92 days.

Corn and legume hay for fattening lambs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Corn Lbs.	Hay Lbs
Corn allowance unlimited				
Shelled corn, 1.3 lbs.				
Clover or alfalfa hay, 1.4 lbs.	67	0.32	400	436
Corn allowance limited				
Shelled corn, 0.9 lb.				
Clover or alfalfa hay, 2.1 lbs.	60	0.32	288	655

The lambs given a full feed of corn consumed an average ration of 1.3 lbs. shelled corn and 1.4 lbs. clover or alfalfa hay and gained 0.32 lb. per head daily, requiring 400 lbs. shelled corn and 436 lbs. hay per 100 lbs. gain. The lambs getting the limited corn allowance ate 0.9

lb. corn and 2.1 lbs. hay per head daily and required 655 lbs. of hay and only 288 lbs. of corn for 100 lbs. of gain. From these averages, the feeder may readily calculate the cost and possible profits of fattening lambs under reasonably favorable conditions, and when the fattening period is not too extended.

Hints on feeding corn.—Being low in protein, corn should be supplemented with some kind of legume hay, or if this is not available then with some protein-rich concentrate, such as linseed or cottonseed meal, when fed to fattening sheep or lambs. In each of 7 trials at various stations corn and timothy or prairie hay was fed to one lot of lambs and corn and clover or alfalfa hay to another. On the average, the lambs fed the legume hay gained 0.32 lb. per head daily, while those fed the unbalanced ration of corn and timothy or prairie hay gained only 0.19 lb. and required 46 per ct. more grain and 15 per ct. more hay per 100 lbs. gain. In 4 other trials, corn and timothy hay were fed to one lot of lambs, while another received these feeds and 0.2

FIG. 94. SHEEP ON WESTERN RANGE GRAZED UNDER THE "MASS" METHOD

From such grazing lands as these come the western lambs fattened in feed lots in the western states, in the corn belt, and eastward. (From U. S. Department of Agriculture.)

lb. of linseed or cottonseed meal per head daily. Balancing the ration increased the gains over 30 per ct. and saved over 11 per ct. of the concentrates and 25 per ct. of the hay required for each 100 lbs. gain.

Trials at the Iowa[1] and Illinois[2] Stations show that it rarely pays to grind corn for fattening lambs, except perhaps where they are already fairly fat and it is desired to continue feeding them for some time. Shelled corn is most commonly fed to sheep but ear corn and broken ear corn are satisfactory. Excellent results are secured when lambs are fed ear corn at first, changed to broken ear corn as the feeding progresses, and finished on shelled corn or coarsely ground corn; i. e., increasing the preparation as the lambs fatten.

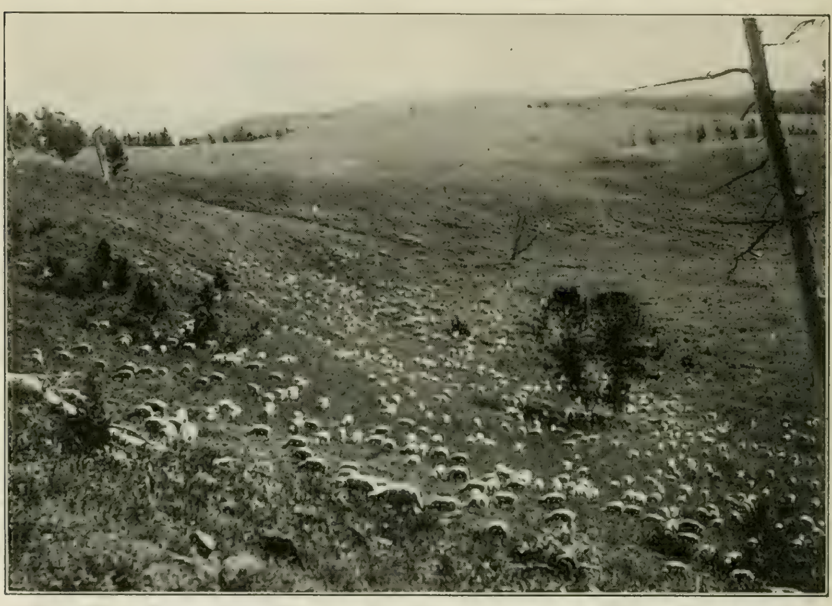

FIG. 95. SHEEP ON RANGE GRAZED UNDER THE "OPEN" METHOD

When sheep are grazed under this improved system more can be carried on a given area than under the "mass" method. (From U. S. Department of Agriculture.)

The other cereals.—Barley, wheat, and the grain sorghums are all relatively low in protein and therefore, like corn, should be balanced with legume hay or some protein-rich concentrate. Wheat and bald barley should be crushed or rolled for sheep, but there is not enough gain from grinding the other grains to pay for the expense.

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[1] Evvard, information to the authors.

[2] Coffey, information to the authors.

Barley is extensively used for fattening sheep and lambs thruout the western range district, where but little corn is grown. In trials at various stations lambs fed good heavy brewing or Scotch barley have made nearly as large gains as those fed corn but have required more grain and roughage for 100 lbs. gain. Hence in these trials barley has been worth 16 to 27 per ct. less per ton than shelled corn.

Wheat is rarely fed to sheep unless off grade or low in price. Grain of good quality is slightly superior to barley and practically equal to corn for fattening sheep.

The value of *wheat screenings* varies widely, heavy screenings being equal to wheat, while the light, chaffy grades are more like a roughage than a concentrate. Successful feeders wisely use screenings of low grade in getting the lambs on feed and as fattening advances change to the heavier screenings.

Oats are bulky and, being well liked by sheep, are widely used in starting sheep on grain at the beginning of the fattening period. They are also excellent for the breeding flock. Owing to their usual high price and the fact that they induce growth rather than fattening, it is rarely economical to feed much oats to fattening sheep. Trials at the Indiana Station [3] show that after lambs are on full feed corn as the only grain is as satisfactory as a mixture of corn and oats. When oats were used to replace one-third the corn in a trial at the Nebraska Station,[4] they were worth 23 per ct. less per ton than corn. At the Iowa Station [5] when oats were fed in comparison with corn to lambs with clover hay, corn silage, and enough linseed meal to balance the ration, the oats were worth 31 per ct. less than shelled corn.

Emmer is an important grain for sheep and lambs in the northern plains states. When used as the only grain, it is worth but three-fourths as much as corn per 100 lbs., tho its value is somewhat higher when fed with barley or corn.

Kafir and *milo,* of increasing importance in the southern plains region, are worth slightly less than barley for sheep feeding.

Miscellaneous carbonaceous concentrates.—*Dried beet pulp* is equal to corn for growing or fattening lambs, when fed as part of the concentrates. *Beet molasses* is sometimes fed to sheep in the vicinity of beet-sugar factories in the West. In some cases no other concentrate is fed, and in others wet beet pulp and a little cottonseed cake are added to the ration. To avoid smearing the wool, the molasses is

[3] Skinner and King, Indiana Buls. 168, 179, 184.

[4] Gramlich, Nebr. Station, information to the authors.

[5] Evvard and Dunn, Iowa Station, information to the authors.

preferably mixed thoroly with cut hay or straw. *Hominy feed* is about equal to shelled corn for fattening lambs.

Linseed and cottonseed meal.—These protein-rich concentrates are the supplements most commonly used with sheep for balancing rations low in protein. In 2 trials at the Wisconsin Station[6] the value of these supplements was compared when added to a ration of shelled corn, corn silage, and legume hay—a ration low in protein. As cottonseed meal is slightly richer than linseed meal in protein, slightly less was needed to balance the ration. Both years there was practically no difference in the gains of the 2 lots, in the amount of feed required for 100 lbs. gain, or in the finish of the lambs. Since it was not necessary to use as much cottonseed meal as linseed meal to balance the ration, the cost of the gains was slightly less with cottonseed meal. Lambs should not receive more than half a pound of linseed or cottonseed meal per head daily, and one-eighth or one-fourth pound is usually enough to balance the ration. Linseed cake of pea size is better relished by sheep than the finely ground meal.

Minor protein-rich concentrates.—*Field peas* and *soybeans* are usually too expensive to form the entire concentrate allowance for fattening lambs, but may be used with corn or other grain. Field peas produce firm flesh and fed in combination with such feeds as corn, oats, and bran are excellent in fitting sheep for shows.

Wheat bran should form no large part of the concentrate allowance for fattening sheep, for, like oats, it induces growth rather than fattening and is too bulky. When lambs are being started on feed, bran is useful for mixing with corn and other heavy concentrates to prevent digestive troubles. It is a most valuable feed for breeding ewes.

Dried distillers' grains, dried brewers' grains, and *gluten feed,* tho not commonly fed to sheep in this country, have given good results in Europe.

II. Roughages for Sheep

Legume hay.—The legumes furnish by far the best roughages for sheep—in the East clover and alfalfa hay, thruout the West alfalfa with clover and field peas in certain sections, and in the South the cowpea, beggarweed, and other plants. It is more important for sheep than for cattle that the hay be fine-stemmed and leafy.

The superiority of legume hay over carbonaceous hay for sheep is shown in the following summary of 5 trials at 4 different stations, in which rations of clover or alfalfa hay with corn as the sole concentrate have been compared with rations of timothy or prairie hay and corn and cotton- or linseed meal, which were equally well balanced so far as the amount of protein was concerned.

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[6] Morrison and Kleinheinz, unpublished data.

Legume hay vs. carbonaceous hay for fattening lambs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Concentrates Lbs.	Feed for 100 lbs. gain Hay Lbs.
Legume hay				
Clover or alfalfa hay, 1.5 lbs.				
Corn, 1.3 lbs.	63	0.32	388	455
Carbonaceous hay				
Timothy or prairie hay, 1.0 lb.				
Corn, 1.0 lb.				
Cotton- or linseed meal, 0.2 lb.	63	0.24	505	422

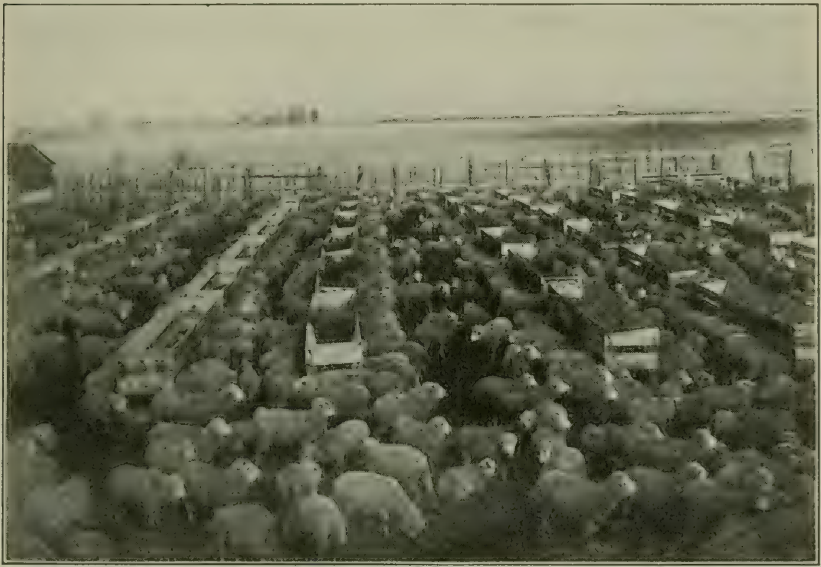

FIG. 96. FATTENING LAMBS IN A WESTERN FEED LOT

In the western states no shelter except a windbreak is commonly provided for fattening lambs. In the corn belt and eastward shelter is required to protect the lambs from winter storms. (From *Wallace's Farmer.*)

Tho the lambs fed timothy or prairie hay received a well-balanced ration, those on clover or alfalfa made much larger gains and required less feed per 100 lbs. gain.

Fattening lambs given all the corn and legume hay they will eat consume enough of the protein-rich hay, even toward the end of the fattening period when on a full feed of grain, to balance the ration quite well. Indeed, the data for 10 trials at various stations show that adding linseed or cottonseed meal to a ration of corn and legume hay increased the average daily gain only 0.01 lb. and did not lessen the amount of feed required for 100 lbs. gain.

Legume hays compared.—Early-cut *red clover hay* is one of the best roughages for sheep, both for fattening animals and for the breeding flock. *Alfalfa hay* has about the same value as clover, except that, being richer in protein, less is needed to balance a ration otherwise low in this nutrient.

Cowpea hay gives good results with sheep, tho somewhat less valuable than alfalfa hay. *Sweet clover hay* is a satisfactory roughage for sheep, but is inferior to alfalfa hay. In certain sections of the West large numbers of lambs are fattened by grazing on *field peas,* usually sown with a small quantity of oats or barley to support the vines. The lambs are turned in the fields when most of the peas have matured and are fattened in 70 to 120 days, commonly without other feed. Sometimes the peas are cut, stacked, and fed to the lambs in yards.

Timothy and other carbonaceous hay.—*Timothy hay* is unsatisfactory for sheep, being both unpalatable and constipating. The dry heads of this grass work into the wool, irritating the skin, lowering the value of the wool and making shearing difficult. As has been shown before, even when a nitrogenous supplement is added to timothy hay and corn, the ration is still inferior to one of legume hay and corn. *Marsh hay* is too coarse and woody for sheep, and *millet hay* is also unsatisfactory. *Bluegrass hay* and bright *oat straw* are preferable to any of these. Western *prairie hay,* tho more palatable than timothy, is much inferior to alfalfa. *Sorghum hay* ranks with corn stover, its value depending on its fineness.

Corn stover and corn fodder; straw.—Next in value to hay from the legumes come the dried leaves of the corn plant. For sheep feeding, corn should be cut early and cured in well-made shocks. The sheep will eat a little more of the stalks if shredded, but cutting does not induce them to consume any of the coarser parts. Neither corn stover nor straw should be fed as the only roughage, tho some may often be utilized with profit when given with other more palatable roughage, such as legume hay and corn silage. In a trial at the Oklahoma Station [7] lambs fed 0.8 lb. corn stover, 0.7 lb. alfalfa hay, 1.2 lbs. corn, and 0.4 lb. cottonseed meal per head daily, made nearly as large gains as others fed 1.5 lbs. alfalfa hay and 1.6 lbs. corn, and required but little more concentrates for 100 lbs. gain.

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[7] McDonald and Malone, Okla. Bul. 78.

III. Succulent Feeds

Roots.—Roots, silage, pasture and other succulent feeds are exceedingly beneficial to the flock because of their tonic and regulative effect. Roots are universally fed in large amounts to sheep in Great Britain, famed for mutton of the highest quality. While even lambs are sometimes there fed over 20 lbs. of roots per head daily, in this country it is not ordinarily profitable to feed over 4 or 5 lbs., and even half this much, preferably pulped or sliced, will furnish the needed succulence in the ration.

Averaging the results for 5 trials in which roots have been added to a well-balanced ration of grain and alfalfa, clover, or mixed clover and timothy hay, we find that the lambs fed roots (3.7 lbs. per head daily) gained 22 per ct. more than those fed no roots. In these trials 1 ton of roots replaced 174 lbs. of grain and 355 lbs. of hay.

At the Iowa Station[s] sugar beets ranked first in amount and economy of gain, with mangels second, and turnips third. Since mangels and sugar beets when fed to sheep tend to produce calculi, or stones, in the kidneys or bladder, which are dangerous in the case of rams and wethers, these roots should not be fed to males for long periods. In the Iowa trials rams died after being fed on rations containing 4.4 lbs. of sugar beets or mangels for 5 to 6 months. Ewes are not so affected.

Corn silage.—Trials by American stations show that in most parts of this country corn silage is as satisfactory and usually a much more economical succulent feed than roots. In 2 trials lambs fed corn silage, hay, and concentrates made as large gains as others fed roots, hay, and concentrates; in 1 trial, larger gains; and in 4 trials, somewhat smaller gains. On the average the lambs fed roots gained only 0.02 lb. more per head daily than those fed corn silage. Due to the more watery nature of the roots, 1,000 lbs. of silage replaced 1,449 lbs. of roots.

The value of corn silage for fattening lambs is well shown in the following table, which summarizes 8 trials in which it was added to the already excellent ration of clover hay and shelled corn:

Value of corn silage when added to well-balanced ration

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain		
			Corn Lbs.	Hay Lbs.	Silage Lbs.
Lot I					
Corn silage, 1.35 lbs. Clover hay, 0.95 lb. Shelled corn, 1.15 lbs.	61	0.316	366	308	428
Lot II					
Clover hay, 1.57 lbs. Shelled corn, 1.24 lbs.	61	0.313	397	507	...

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[s] Kennedy, Robbins and Kildee, Iowa Bul. 110.

On the average, the lambs fed silage ate 0.62 lb. less hay and 0.09 lb. less corn daily, yet gained slightly more than those fed clover hay and shelled corn. Adding silage to a ration of clover hay and corn does not, however, always result in increased gain, for in 4 of these trials the lambs fed no silage made the larger gains. Its advantage lies rather in the saving of corn and hay required for 100 lbs. of gain. In these trials 100 lbs. of corn silage saved 7.2 lbs. of corn and 46.5 lbs. of clover hay. With corn at $.56 per bushel and clover hay at $14.00 per ton, the silage fed had a value of $10.45 per ton, or about twice the cost of production on most farms. Besides cheapening the gains, in these trials the addition of silage to the ration usually resulted in higher finish and consequently in a greater selling price. Corn silage of good quality is as valuable for the breeding flock as for sheep being fattened for market, but feeding too much silage to ewes may produce weak lambs.

Hints on feeding silage.—Trials at the Indiana Station[9] show that lambs fed corn silage as the sole roughage make considerably smaller gains than where they are fed legume hay in addition, and more care is required to prevent their going "off feed." In still other trials[10] it was found best to allow the lambs all the silage they will eat, both morning and night, with free access to legume hay, rather than limiting the amount of silage fed.

It has already been shown in this chapter that adding a protein-rich concentrate, such as cottonseed or linseed meal, to the already well-balanced ration of corn and legume hay is not ordinarily profitable. When corn silage is added to a ration of corn and legume hay, all being fed in unlimited allowance, the lambs will eat less of the protein-rich hay, the ration thus becoming somewhat unbalanced. In trials at the Indiana Station[11] feeding 1 part of cottonseed meal to 7 parts of shelled corn increased the daily gains 0.02 lb. and slightly decreased the amount of feed required for 100 lbs. gain. Feeding more cottonseed meal than this did not increase the gains. In some cases more profit was made when no cottonseed meal was fed, owing to the fact that it was considerably higher in price than corn. Whether to add a protein-rich concentrate to a ration of corn, corn silage, and legume hay must be determined by each feeder for himself, after taking into consideration the prices of feeds, the value of the manure, and the time the animals should be ready for the market.

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[9] Skinner and King, Ind. Buls. 168, 179.

[10] Coffey, Ill. Sta., information to the authors; Skinner and King, Ind. Bul 168.

[11] Skinner and King, Ind. Buls. 162, 168, 179; information to the authors.

The numerous instances in which sheep of all classes have died from eating moldy or decayed silage show that greater care is necessary in administering this feed to sheep than to cattle. As sour silage is apt to cause colic and scouring, silage for sheep should be made from well-matured corn.

Silage other than corn.—Sorghum silage from plants sufficiently matured to produce silage low in acidity is satisfactory for sheep, and may be used in the same manner as corn silage. Where the field pea flourishes, the whole plant may be profitably ensiled for sheep fattening. In the vicinity of pea canneries, fattening sheep and lambs on ensiled pea vines and pods is an important industry, especially in Wisconsin. Some dry roughage, such as corn stover or hay, is supplied in addition to the silage, and grain or screenings are fed, particularly during the latter part of the fattening period.

Wet beet pulp.—This by-product is extensively fed to fattening sheep in the vicinity of the beet-sugar factories in the western states. Sheep are commonly given all the pulp they will eat, along with alfalfa hay, which admirably supplements the pulp, low both in protein and lime. Feeding a limited allowance of corn, barley, or other grain in addition, is usually advisable. At the Colorado Station,[12] 1 ton of wet beet pulp was equal to 200 lbs. of corn for fattening sheep. Pulp is commonly fed to old ewes and wethers, but seems too bulky for the best results with lambs. It is especially suited to old animals with poor teeth.[13]

Pastures for sheep.—As sheep relish weeds and browse eagerly on sprouts and brush refused by other stock, they are helpful in cleaning up the farm, especially such by-places as lanes and fence corners. Of the permanent pastures, bluegrass is the most common in the upper Mississippi valley and eastward. Farther south red top is prominent, and in the southern states Bermuda grass. In the West the native grasses, especially the grama species, furnish much of the grazing on the ranges, tho on mountain ranges the food is often mostly herbs and the leaves and twigs of shrubs.[14]

The clovers furnish valuable pasture, but great care is necessary to prevent bloat when sheep are grazed on them. Alfalfa is especially liable to cause bloat and can be recommended as a pasture plant for but few sections, altho some skillful flockmasters suffer little loss. In some parts of the West alfalfa is utilized for winter grazing, as it is then so lacking in succulence that danger from bloat is practically absent. In the humid regions care is always necessary to prevent trouble from stomach worms when permanent pastures are used.

[12] Colo. Bul. 76.

[13] Morton, Colo. Sta., information to the authors.

[14] Beattie, Wash. Bul. 113.

Experienced shepherds commonly grow annual crops to supplement permanent pastures when they are short. The earliest grazing is usually furnished by the cereals, the best of which, according to Shaw,[15] is winter rye. Rye is also grown for fall grazing and in sections with moderate winters winter wheat furnishes feed during the colder months. The sorghums are useful in the plains region, altho not especially relished by sheep. Where they flourish, field peas, vetches, cowpeas, and crimson and Japan clover all furnish excellent pasture.

Rape is the most widely useful member of the mustard family, which furnishes several other grazing crops. At the Wisconsin Station,[16] rape proved much superior to bluegrass pasture for lambs. The best results are secured when rape and bluegrass are used in combination. In pasturing rape, care is necessary to avoid losses from bloat, just as in pasturing clover. In the mild climate of the Pacific coast where it endures the winter, kale provides excellent spring feed. In the fall kohlrabi and cabbage may be useful. Both rutabagas and turnips are widely grown in Britain for grazing. Shaw suggests these winter crops for winter grazing in the southern states.

QUESTIONS

1. About how large gains should good lambs make and about how much feed will they eat per 100 lbs. of gain (a) when fed an unlimited allowance of corn and legume hay; (b) when the corn allowance is limited?
2. What is the value for sheep of barley, wheat, wheat screenings, oats, emmer, and kafir compared with corn?
3. State the value and uses for sheep of at least four protein-rich concentrates.
4. Discuss the importance of legume hay for fattening lambs.
5. Compare the value of four kinds of legume hay for sheep.
6. To what extent would you use carbonaceous roughages for sheep?
7. In your own section would you use roots or silage for sheep? Why?
8. Discuss the use of corn silage for sheep.
9. What other kinds of silage are useful for sheep?
10. What is the value of wet beet pulp for sheep fattening?
11. What pasture crops are suitable for sheep in your district? State the precautions you would take in grazing sheep on clover.
12. Using local prices for feeds, compute the ration you would recommend for fattening lambs weighing 75 lbs. per head. Follow the method described in Chapter VIII and use the Morrison feeding standards.

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[15] Management and Feeding of Sheep, p. 171.

[16] Craig, Wis. Rpt. 1897.

CHAPTER XXVII

FEEDING AND CARE OF SWINE

I. GENERAL PROBLEMS IN SWINE HUSBANDRY

The pig excels all other farm animals in the economy with which he converts feed into edible flesh, requiring but 4 to 5 lbs. of dry matter to produce a pound of gain, while fattening cattle require from 10 to 12 lbs. The pig yields from 75 to 80 per ct. of his live weight as dressed carcass; the steer only 55 to 65 per ct. Moreover, pigs will profitably utilize many by-products of the farm otherwise lost, such as dairy by-products and kitchen and garden waste, as well as grains that cannot otherwise be disposed of profitably. No other line of stock farming can so quickly be brought to profitable production with limited capital invested in stock and equipment as can the making of meat from the pig. Due to this efficiency in producing human food, pigs steadily increase in importance as population becomes more dense.

Practically every farmer should raise and fatten pigs, for family consumption if not for market, in order to save feed that would otherwise be wasted. In many cases he should not only fatten his pigs but also slaughter them and market the cured products, obtaining increased profits even tho the undertaking be a small one.

Rate and economy of gains by pigs.—The economy with which pigs of different weights convert feed into meat is shown in the following table, summarizing the data from over 500 feeding trials with more than 2,200 pigs at many American experiment stations. In this table 6 lbs. of skim milk or 12 lbs. of whey is rated as equal to 1 lb. of concentrates.

Relation of weight of pigs to feed consumed and rate of gain

Wt. of pigs	Actual av. wt.	No. of animals fed	Av. feed eaten per day	Feed eaten daily per 100 lbs. live weight	Av. gain per day	Feed for 100 lbs. gain
Lbs.	Lbs.		Lbs.	Lbs.	Lbs.	Lbs.
15 to 50	38	174	2.2	6.0	0.8	293
50 to 100	78	417	3.4	4.3	0.8	400
100 to 150	128	495	4.8	3.8	1.1	437
150 to 200	174	489	5.9	3.5	1.2	482
200 to 250	226	300	6.6	2.9	1.3	498
250 to 300	271	223	7.4	2.7	1.5	511
300 to 350	320	105	7.5	2.4	1.4	535

This table points out several facts of great importance to the pork producer. While the amount of feed eaten per head daily increases as the pigs grow larger, the amount consumed per 100 lbs. live weight decreases rapidly. In other words, young pigs have a greater capacity for consuming feed than older ones per 100 lbs. live weight. The average gain per day started at 0.8 lb. for pigs weighing under 50 lbs. and gradually increased until those weighing 250 to 300 lbs. showed a daily gain of 1.5 lbs. The last column, perhaps the most important, shows that as the pigs grow older, they require more and more feed for 100 lbs. gain, the gains thus constantly becoming more expensive. The greater production from the younger pigs is due chiefly to the fact that they consume more feed per 100 lbs. live weight and consequently have a greater surplus from which to make gain after their bodies are maintained. Also, 100 lbs. of gain made by 150-lb. pigs has somewhat less food value than the same amount made by 250-lb. pigs, for the gain of the younger pigs contains more water and less fat. Due to the increased cost of the gains as they mature, most pigs are now marketed when weighing only 250 lbs. or less.

Nutrient requirements of swine.—Since pigs are commonly fattened for market before maturity, they are growing rapidly as well as storing fat in their bodies. Consequently their ration should supply ample protein and mineral matter for normal growth. The requirements of pigs of various ages, as shown in studies by the junior author of the numerous trials at American experiment stations, are given in the Modified Wolff-Lehmann standards.

We have seen in Chapter IV that since horses, cattle and sheep eat large quantities of hay, which is relatively rich in calcium (lime), their rations ordinarily contain plenty of this mineral nutrient. Pigs, however, are not fitted to consume much roughage and are fed chiefly on the cereal grains, which are low in calcium. There is, therefore, much more danger that their rations may not contain sufficient calcium for thrifty growth of the skeleton and body tissues. Pigs on such pasture as alfalfa, clover, or rape, and those fed skim milk or tankage as supplements to corn or other grains, will ordinarily receive sufficient calcium. When fed in the dry lot on cereal grains and their by-products, they should be given additional calcium in the form of ground limestone, bone ash, or ground rock phosphate. An abundant supply of calcium is especially necessary for young pigs and brood sows. When rations are so balanced that they furnish sufficient protein to meet the feeding standards, they will also supply enough phosphorus for rapid growth. This is due to the fact, brought out in Chapter V, that the common feeds which are rich in protein are also high in phosphorus.

Grinding or soaking grain.—To find whether it was profitable to grind corn for fattening pigs, the senior author, at first alone and later with Otis, conducted 18 trials at the Wisconsin Station[1] during 10 consecutive winters with pigs averaging 175 lbs. in weight at the beginning of the trials. In each trial one lot was fed a ration of two-thirds year-old shelled dent corn and one-third wheat middlings, and the other lot wheat middlings and the same corn ground to meal. In 11 of the trials grinding the corn saved from 2.5 to 18.5 per ct. in the amount of feed needed for 100 lbs. gain, while in the other 7 trials shelled corn gave the best results. On the average, it required 501 lbs. of whole corn and wheat middlings and only 471 lbs. of ground corn and middlings for 100 lbs. gain, a saving of 6 per ct. This means that with corn at $1.50 per bushel grinding would save 9 cents on each bushel, allowing nothing for labor or expense. It was observed that the pigs fed ground corn ate more in a given time and gained faster than those getting shelled corn. This no doubt explains the

FIG. 97.—THE SCOOP SHOVEL METHOD OF PREPARING CORN FOR PIGS

For pigs under 150 lbs. in weight, shelling or grinding corn does not increase its value. For older pigs the saving by grinding is only 4 to 6 per ct. (From Iowa Station.)

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[1] Wis. Rpt. 1906.

impression of many farmers that pigs do better on ground than on whole corn.

Later trials at the Indiana [2] and Iowa [3] Stations show that until pigs reach a weight of about 150 lbs. there is no appreciable benefit from grinding corn or even shelling it, ear corn producing the cheapest gains. However, after pigs have reached this weight, they chew their feed less thoroly and therefore usually make slightly more rapid gains and require somewhat less feed per 100 lbs. gain if the corn is either ground or soaked. Whether this saving, which will average 4 to 6 per ct., will cover the cost of preparation must be decided by the feeder.

With the small grains, such as wheat, barley, oats, and the grain sorghums, more of the grain passes thru the animal unmasticated, and therefore grinding pays, even for pigs under 150 lbs. in weight. In 9 trials at 5 stations in which pigs were fed whole or ground wheat, rye, oats, barley, or peas, there was an average saving of 12 per ct. by grinding. Where the grain can not be conveniently ground, it should be soaked for about 12 hours, but not allowed to ferment.

Cooking feed.—Early agricultural authorities strongly advocated cooking feed for swine, but numerous trials at several stations have proved conclusively that, instead of a gain from cooking, there is in nearly every case a loss. In 26 trials in which pigs were fed either cooked or uncooked grain (corn, barley, rye, peas, or wheat shorts, fed separately or in combination), 89.4 lbs. of uncooked grain was as valuable, on the average, as 100 lbs. of the same grain when cooked, a loss of over 10 per ct. by cooking. Some few feeds, such as potatoes and field beans, are improved by cooking. In winter slop should be warmed, but not cooked, for pigs in cold quarters.

Water required by pigs.—Dietrich,[4] who has given the subject careful study, concludes that the proper amount of water for pigs ranges from 12 lbs. daily per 100 lbs. of animal at weaning time down to 4 lbs. per 100 lbs. live weight during the fattening period. Unless pigs secure plenty of water in the form of slop, they should be supplied with fresh water in a trough or by means of an automatic waterer. Dietrich holds that pigs do not usually drink enough water in winter, and should be forced to take more by giving it, warm if necessary, in their slop.

There is generally no advantage in wetting feeds, unless the pigs will not otherwise drink enough water. When wheat meal is fed, it forms a pasty, gummy mass in the mouth, difficult to chew and swallow; feeding it as a thin slop largely prevents this trouble.

[2] King, Proc. Amer. Soc. Anim. Prod., 1913, pp. 22–31.
[3] Kennedy and Robbins, Iowa Bul. 106.
[4] Swine, p. 156.

Self feeders.—Evvard of the Iowa Station [5] has conducted numerous trials with self feeders for various classes of swine. His results show that this method of feeding is well adapted to the quick fattening of well-grown shotes, for fattening old sows, and for growing, fattening shotes where it is desired to feed them an unlimited grain allowance.

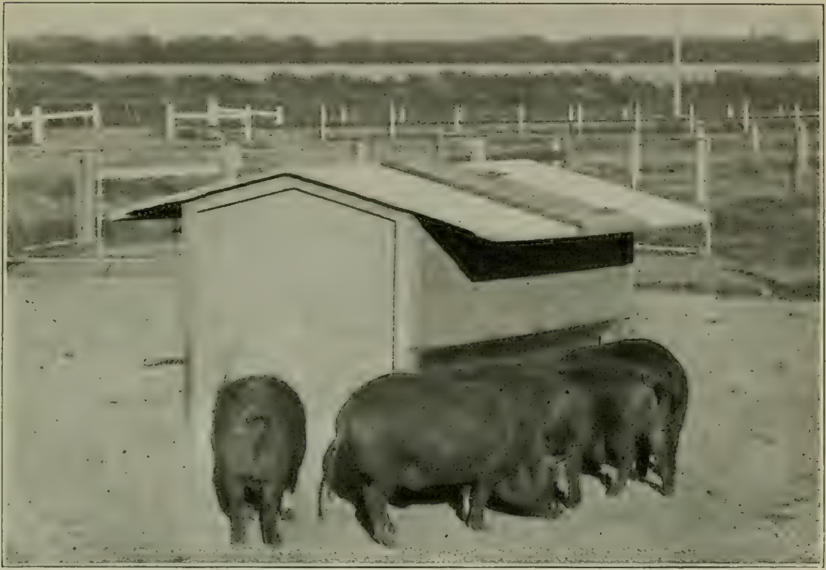

FIG. 98.—FATTENING PIGS WITH A SELF FEEDER

Pigs self-fed on corn and tankage, with or without other supplements, make rapid and economical gains. (From Evvard, Iowa Station.)

The self feeder should not be used when rapid gains are not wanted, for instance, where it is desired to force pigs to make the maximum use of pasturage by limiting the grain allowance. It should not be used for growing pigs for the breeding herd, or for pregnant sows, unless some bulky feed, such as ground alfalfa, is mixed with the grain. Otherwise they will become too fat. Much skill is required to keep the feeds so proportioned that the animals will not become too fat or too lean. Therefore, hand feeding such animals is commonly preferable.

The large and economical gains which may be secured with growing pigs self-fed in dry lots on corn and suitable supplements are shown in a trial in which 45-lb. pigs were allowed access to shelled corn and various supplements in separate self feeders for 162 days. Salt, charcoal, and ground limestone were supplied in addition. The pigs in one lot, consuming an average ration of 6.0 lbs. shelled corn, 0.08 lb. oats, 0.10 lb. linseed meal, and 0.40 lb. tankage, gained 1.6 lbs. per head daily. They reached an average weight of 316 lbs. at 248 days of age, one of them weighing 405 lbs., an unusual record. This lot required 417 lbs. of concentrates for 100 lbs. gain. Nearly as large gains were made by a second lot, fed shelled corn, oats, and meat meal, and by a third lot, fed shelled corn, oats, wheat middlings, linseed meal, and meat meal.

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[5] Proc. Amer. Soc. Anim. Prod., 1914.

Evvard states that pigs allowed free access to corn and supplements, such as tankage, linseed meal, and wheat middlings, show a remarkable ability to balance their own ration. At first about 75 per ct. of the entire ration was corn and the remainder meat meal and other supplements. As the pigs grew older they widened the nutritive ratio till at the close about 99 per ct. of the feed eaten was corn. All lots ate a larger proportion of oats during the first few weeks than later, consuming only an insignificant amount of this bulky feed when they became well fattened. When pigs are not supplied all the corn they will eat it is inadvisable to feed tankage in a self feeder, for because of hunger they will eat more meat meal than is needed to balance their ration.

Salt and correctives of mineral nature.—Tho pigs require less salt than the other farm animals, they should be supplied with it regularly. In a trial by Evvard at the Iowa Station[6] pigs allowed free access to salt made better gains than those receiving no salt or others getting allowances of one-sixty-fourth, one-thirty-second, or one-sixteenth ounce per head daily. Salt may be supplied in a trough or a small self feeder. If pigs have not had free access to salt they may at first overeat.

Since the cereal grains are all very low in lime, when pigs are fed only on cereals and their by-products they will not secure enough lime for normal growth. Due to this, pigs when not on pasture often greedily devour such substances as ashes, mortar and even soft coal. For pigs kept in confinement such correctives as charcoal and sulphur are believed by many to be advantageous. Therefore, it is advisable to keep some such mineral mixture as the following constantly before swine when not on pasture: 100 lbs. ground limestone, 100 lbs. wood ashes, 200 lbs. ground charcoal, 50 lbs. salt, and 20 lbs. sulphur.

Shelter and exercise.—Even in the northern part of the corn belt, where the winters are severe, inexpensive shelter is all that is necessary for swine. The requisites for healthful winter shelter are freedom from dampness, good ventilation without drafts on the animals, sunlight, reasonable warmth, and a moderate amount of dry bedding.

[6] Information to the authors.

The quarters should be located on well-drained ground and should be so arranged that they may be easily and thoroly cleaned and disinfected.

Swine may be housed in a central hog house having a number of pens or in small movable "cabins" or colony houses. Many use a combination of the two systems, for in the northern states the central house is well suited for winter shelter and spring farrowing, while the portable houses are particularly useful for housing pigs on pasture. Pigs wintered in colony houses, especially young ones, require considerably more feed than those in warmer quarters. This is more or less offset by the low cost of the cabins and by the ease with which they may be shifted to prevent disease and parasites and to distribute the droppings of the animals. In severe weather corn stalks, horse manure, or other litter may be banked against the sides of the houses. With liberal bedding, all but very young pigs should then be comfortable. When litters come in severe weather a lantern hung in the cabin will usually furnish sufficient warmth.

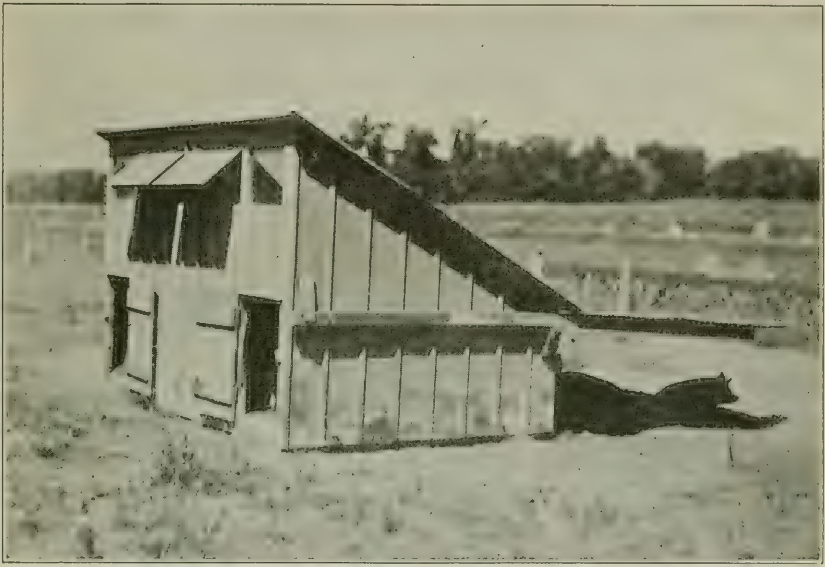

FIG. 99.—ONE TYPE OF COLONY HOUSE FOR PIGS

Colony houses, which are of several types, are especially useful for housing pigs on pasture. Note the shade at the rear of this house. (From Fuller, Wisconsin Station.)

For breeding stock and growing pigs ample exercise is of the utmost importance. To enforce exercise the animals may be fed at a point some distance from the central house or the colony houses where there are troughs and a feeding floor. When snow covers the ground, paths to this place can be broken out with a snow plow. On the feeding floor, which should be kept clean and should be covered if possible, shelled corn and whole oats may be scattered thinly to force the sows or pigs to pick up a grain at a time. Thus they may be kept out of their beds and on their feet for hours getting air and exercise.

Types of swine; breed tests.—The principal breeds of swine are of two distinct types, the lard type, of which the Poland-China, Berkshire, Chester-White, and Duroc-Jersey are the leading breeds, and the bacon type, represented by the Tamworth and Large Yorkshire breeds. The Hampshires, tho often classed as bacon hogs, really stand between the extreme bacon type and the lard type. Lard hogs, which are the type commonly raised in the United States, have compact, wide, and deep bodies. Since the hams, back, and shoulders are the most valuable parts, the packer desires a hog furnishing a maximum of these cuts. Usually being well-fattened, lard hogs yield a high percentage of dressed carcass. Formerly heavy hogs were in largest demand, but now pigs weighing 225 lbs. or less will command the highest price under usual conditions.

During the past few years the "big type" of the lard breeds has come into wide favor and is largely displacing the former extreme lard type. These hogs are more heavily and strongly boned, are longer and taller, and are more prolific. At a given weight they will carry less fat than the extreme lard type. Due to this and also to their greater vigor they make more economical gains in weight.

The bacon pig is raised chiefly in Denmark, Great Britain, and Canada, where corn is not the main feed for swine. Pigs of the bacon breeds are longer of body and of leg than those of the lard breeds, have less thickness and depth of body, and are lighter in the shoulder, neck, and jowl. For bacon the pigs should weigh from 160 to 200 lbs. and carry but medium fat, from 1 to 1.5 inches thick along the back.

Breed tests have been conducted at several stations to determine whether there is any difference in the economy of meat production by the different breeds. There was no consistent and uniform difference in gains or economy of production, a breed which ranked high in some of the tests being surpassed by other breeds in the rest of the trials. One should select the breed which seems best adapted to his conditions and suits his fancy, and then be sure to secure and to maintain vigorous, well-bred animals of that breed.

The brood sows.—The most important points in the feed and care of brood sows are: (1) Rations rich in protein and mineral matter;

(2) the right amount of feed—not too much or they will get too fat; (3) plenty of exercise; (4) comfortable quarters—dry, well-ventilated, and well-lighted; (5) freedom from constipation, worms, and lice.

Where sows raise but one litter of pigs a year, they need little or no concentrates in summer after their litters are weaned, provided they run on first class pasture, such as alfalfa, clover, or rape. Enough grain should be fed to keep the sows in thrifty condition, and in any event they should get some grain for several weeks before farrowing. On good pasture such concentrates as corn, barley, or other cereals should form most of the ration, with enough protein-rich concentrates to balance the ration. Where sows raise two litters a year they will require more feed, due to the added draft on their bodies.

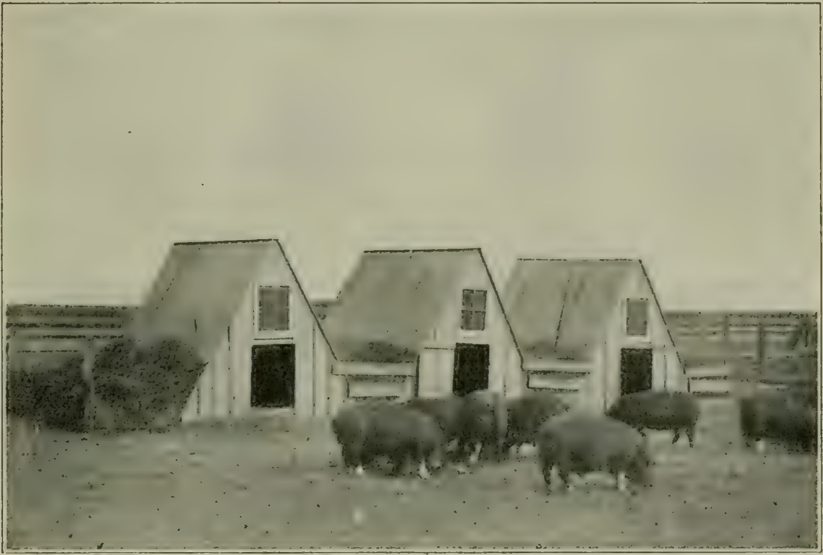

FIG. 100.—COLONY HOUSES BANKED WITH STRAW FOR WINTER

Colony houses thus protected provide comfortable winter quarters for all but small pigs, even in the northern states.

In winter it is essential that sows be fed rations containing plenty of protein and mineral matter, especially lime and phosphoric acid, for these are needed in liberal amounts not only for the proper nourishment of the bodies of the sows but also for the development of the unborn young. Sows fed corn alone will usually farrow small litters of weak pigs, due to the fact that corn is low in protein and mineral matter. On the other hand, several trials show that when corn is properly supplemented, it may form the chief part of the ration. The ration should therefore always be balanced by the use of such protein-rich foods as alfalfa hay or clover hay, skim milk, tankage, linseed meal, wheat middlings, and wheat bran, the nutritive ratio of the ration not being wider than 1:6 or 1:7.

Feeding legume hay to brood sows in winter cannot be too highly recommended, for it is rich in protein, lime, and vitamines, it is laxative, and it furnishes bulk to distend the stomach and intestines properly. Indeed, every brood sow should have access to choice legume hay in a rack. If sows will not eat much hay, then 25 per ct. of chopped or ground hay should be mixed with their feed, or leafy chaff which falls from the hay as it is handled in the barn may be soaked and mixed with the concentrates.

The amount of concentrates should be limited so that the sows will not become too fat, but on the other hand they must not be allowed to become too thin. Constipation, a serious trouble with sows, should be warded off by the use of such feeds as linseed meal, legume hay, or roots.

The age at which to breed young sows will naturally depend somewhat on the growth they have made. Seldom is it advisable to breed them until they are 8 months old, and many stockmen prefer to wait until they are 10 to 12 months old. Sows and boars of the larger breeds should reach a weight of 300 lbs. or over at one year if rightly fed and managed. Whether to raise 1 or 2 litters a year will depend on local conditions, considering the winter climate and the feeds available. Where winters are long and severe and the sows and pigs can not be given the best of feed and care, it is best not to attempt to raise 2 litters a year. Under the proper conditions, especially where dairy by-products are available, 2 litters a year can be raised successfully even in the northern portion of the country, the spring pigs coming in March or April and the fall pigs in September or early October.

According to Coburn,[8] young sows carry their pigs from 100 to 108 days and old ones from 112 to 115, the average for all being 112 days. From the records of 1,477 pure-bred sows of 8 breeds Rommel[9] found that on an average there were 9 pigs to the litter, 50.1 per ct. being males and 49.9 per ct. females. Likely sows that are kindly mothers should be retained for breeders as long as 5 or 6 years if possible. Those which produce litters of less than 5 should be discarded.

The boar.—The feed and care of the boar does not differ materially from that of the sows. He should be kept in thrifty condition, neither too fat nor run down in flesh, as either extreme may injure his breeding powers. In summer the boar should run in a pasture lot, and in winter he should have the freedom of a small yard adjoining the

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[7] Snyder, Nebr. Bul. 147.

[8] Swine in America.

[9] U. S. Dept. Agr., Bur. Anim. Indus., Cir. 112.

pen. About 1 lb. of concentrates daily per 100 lbs. live weight is sufficient in summer for fairly mature boars on good pasture. Young boars need enough concentrates to keep them growing thriftily. In winter 2 lbs. of concentrates daily per 100 lbs. live weight with roots and alfalfa or clover hay should suffice. During service the boar requires more feed than at other seasons.

At farrowing time.—About 5 days before farrowing the sow should be separated from the other hogs and placed in a sunny farrowing pen to become accustomed to her surroundings. Her ration should now be reduced and consist of cooling, laxative feeds, such as legume hay, roots, and a slop made largely of wheat bran or shorts, with perhaps linseed meal and ground oats. By enforcing exercise for brood sows, preventing constipation, and keeping them thrifty thru feeding a well-balanced ration, little trouble will be experienced from sows eating their new-born pigs. If a sow has a feverish udder, which often is a result of constipation, a light application of kerosene and lard, well rubbed in, will relieve the pain.

The farrowing place should be comfortable, dry, well-ventilated, and so sheltered that a deep nest is not necessary to prevent the new-born pigs being chilled, for they may be crushed in a deep, bird-like nest. Cut straw or hay, chaff, and leaves are the best for bedding provided they are reasonably free from dust. Long hay or straw may entangle the pigs. A plank fastened with the edge against the wall, placed about 8 inches from the floor and standing out 8 inches from the sides of the farrowing pen lessens the danger of the mother crushing her young. In the case of heavy, clumsy sows, separate the pigs from the dam by placing them in a warm box or barrel for a couple of days. Sows properly handled before farrowing will not usually resent such separation. The pigs will then be safe, and the attendant can pass them to the dam for nourishment at short intervals. A chilled pig may be revived by immersion in water as warm as the hand will bear.

The weights of the pigs at birth range from less than 1.5 lbs. to over 3 lbs., about 2.5 lbs. being the average with our common breeds.

Care of sow and litter.—For the first 24 hours after farrowing only lukewarm water should be given the sow unless she shows a decided desire for feed, when a little thin, warm slop may be offered. The ration for the following 4 or 5 days should be light, after which she should gradually be brought to full feed, as her milk flow increases. The coarse feeds, so useful at other times, must now largely give way to rich concentrates, chiefly corn, barley, or other grains to furnish carbohydrates, with plenty of protein-rich feeds, such as skim milk, tankage, linseed meal, wheat middlings, etc., to balance the ration.

Five per ct. by weight of alfalfa or clover hay may well be included in the concentrate mixture for suckling sows, or they may still be allowed access to legume hay in a rack if pasture is not yet available. The concentrates may be fed in the form of a slop or else fed dry. It is important that sows with litters be fed liberally, for at no other time will feed give such large returns. Good mothers with large litters will usually lose flesh in spite of the most liberal feeding.

Feeding the litters.—Within 2 or 3 weeks the unweaned pigs should be encouraged to eat with the mother by providing slop in a shallow, low-set trough. Because the sucklings cannot fully satisfy their hunger by such provision, there should also be provided additional feed inside a creep, so that the dam cannot get it. In this a rich slop may be furnished in a low trough, or a palatable mixture of concentrates may be fed in a self feeder. Finely ground, dusty concentrates had best be fed to young pigs in a slop, as the dust may irritate the nasal passages. For young pigs dairy by-products, in combination with various ground grains and milling by-products, are easily the best of all feeds. For very young pigs there is nothing better than ground oats, with the hulls sieved or floated out, and red dog flour. Corn, barley, kafir, and milo meal, dark feeding flour, flour wheat middlings, and ground emmer with the chaff removed, etc., may all be freely used for sows and pigs as the young things come on. Soaked whole corn thinly scattered over a feeding floor gives feed and enforces exercise. Pigs well fed before weaning grow faster and draw less on the sow—a matter of importance where the litters are large.

Where 1 litter of pigs is raised a year, the pigs may run with their dams 10 or 12 weeks, or the sow may be allowed to wean her pigs herself. However, when 2 litters are to be raised, the pigs must be weaned at the age of about 8 weeks. The sow should be separated from the pigs and only returned 2 or 3 times long enough for them to empty the udders. On weaning, pigs of the same size should be placed in groups of not over 20 in order that each may receive its share of feed and proper care and attention.

Growing and fattening pigs.—Good pasture should always be provided thruout the entire growing season for all swine, but pasture is especially important for young pigs, as it keeps them growing thriftily and also greatly reduces the cost of the gains made. In addition to such pasture as alfalfa, clover, or rape at least 2 lbs. of concentrates daily per 100 lbs. live weight should be fed, except where pasture is unusually cheap compared with grain, and the allowance of concentrates should never be less than 1 lb. daily per 100 lbs. live weight. Pigs should gain at least one-half to three-fourths pound per day.

In the corn belt, self-feeding pigs on pasture has become a common practice, except for breeding stock. Where the amount of concentrates fed in summer on pasture is limited, the pigs should be finished on all the concentrates they will eat, hand-fed or self-fed, after they have been well grown. In the corn belt when new corn is ready, pigs are quite commonly finished on new ear corn or snapped corn, along with a suitable protein-rich supplement. Turning pigs into standing corn to "hog down" the crop is often an economical practice, as is pointed out in the next chapter.

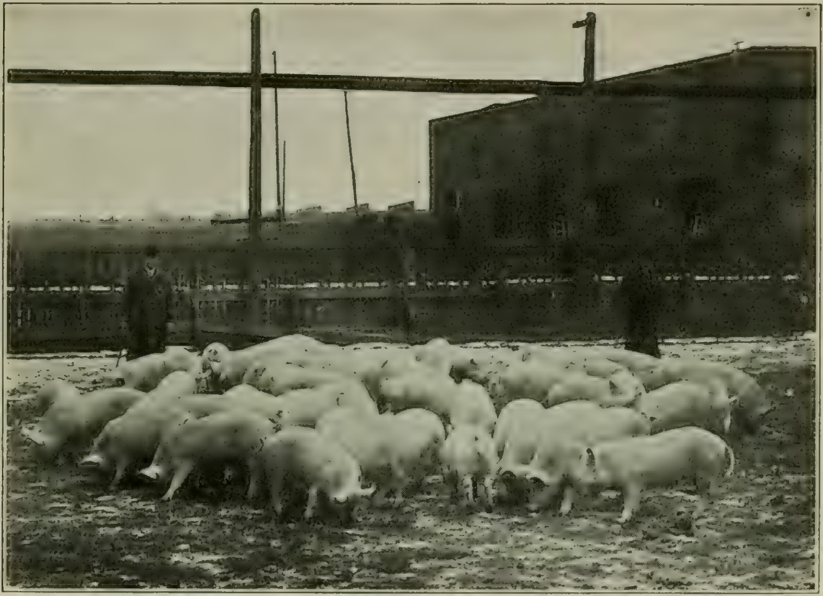

FIG. 101.—A CARLOAD OF BACON PIGS AT THE STOCK YARDS

The Large Yorkshires, shown in the illustration, and the Tamworths have been specially developed for the production of high-quality bacon. Note the length of body and leg of these pigs.

Whether to crowd spring pigs to an early finish by self-feeding them concentrates on pasture or whether to force them to consume more pasture by restricting their concentrate allowance, will depend entirely on the relative prices of grain and pasture and the prices for pork at the various times in the fall and winter. Many corn belt farmers find it most profitable to have the spring pigs farrowed early and then to crowd them on self feeders to an early market, so as to sell them in the fall before the usual slump in the price of pork occurs. In the West where alfalfa pasture or other pasture is cheap, compared with grain, it is usually more profitable to restrict the allowance of grain and finish the pigs for a later market, perhaps after prices have recovered somewhat from the usual fall slump.

Pigs should always be provided with an abundance of fresh water in a trough or an automatic waterer. If self feeders and automatic waterers are used, it should be borne in mind that these labor saving devices do not permit the feeder to forget about his pigs. If he expects good profits he must give them daily attention, seeing that the feeders and waterers are working properly and cleaning them out when necessary—in short see that all is going well with the animals.

Bacon production.—In northern Europe, especially Denmark and Ireland, raising bacon-type pigs and feeding them so as to produce the highest quality of bacon, is an industry of great importance. In this country, however, nearly all the pigs are of the lard type, the bacon on the market being obtained from lard-type pigs which do not carry too much fat. For the production of high-quality bacon, the carcass should show much less fat in proportion to lean meat than in lard hogs, and the fat should be firm and solid. Soft pork unsuited to the production of high-quality bacon is due on the part of the animal to unthriftiness, lack of exercise, immaturity, and lack of finish, and only in a small way to the breed. In general, improper feeding stuffs and feeds improperly combined tend to produce low-quality bacon. Corn, beans, soybeans, and peanuts all tend to produce soft pork. Barley ranks first for bacon production, followed by oats and peas. Skim milk and whey in combination with the cereal grains, including corn in limited amount, make good bacon. Rape, roots, and clover are helpful, but too much succulent feed should not be used. For choice bacon, pigs should be fed slightly less than the full ration.

QUESTIONS

1. Compare pigs with the other farm animals in economy of gains.
2. Discuss the nutrient requirements of swine.
3. Does it pay to grind corn or other grain for pigs?
4. What feeds would you cook for pigs?
5. Tell about (a) the water requirements of pigs; (b) the requirements for salt and mineral correctives.
6. When would you use self-feeders for swine?
7. Discuss the subjects of shelter and exercise for swine.
8. Describe the types of swine.
9. Point out briefly the most important points in feeding and caring for brood sows.
10. How would you feed the boar?
11. Tell about the feed and care of the brood sow before and after farrowing.
12. Discuss (a) the feeding of young pigs; (b) finishing shotes for market; (c) bacon production.

CHAPTER XXVIII

FEEDS FOR SWINE

I. Carbonaceous Concentrates

The digestive organs of the pig are of limited capacity compared with those of other farm animals, for pigs have neither the large fourfold stomach of ruminants nor a cæcum of large size, as has the horse. While in cattle the digestive organs with their contents comprise over 14 per ct. of the total weight of the body, in pigs they make up but 7 per ct. of the body weight. Pigs therefore require feed that is more concentrated and digestible and less woody than do horses, cattle, and sheep. In nature the pig is an omnivorous feeder, living not only on the seeds, leaves and tender stems and roots of plants, but on animal matter as well. Moreover, he lives close to the earth, gathering some of his food from beneath the surface and swallowing considerable earthy matter in so doing. The intelligent swine feeder bears all these facts in mind in feeding his herd.

Indian corn.—This imperial fattening grain is the common hog feed in the great pork-producing districts of America. As has been pointed out before, corn is low in protein compared with its wealth of carbohydrates and fat, and is also deficient in mineral matter. Hence, even for fattening well-grown pigs, much larger and more economical gains are secured when this grain is properly supplemented by feeds rich in protein and mineral matter, especially calcium, or lime. This is clearly shown in the following table, which summarizes the results of 32 trials at various stations, averaging 82 days, in each of which one lot of pigs was fed corn alone and another lot corn and a protein-rich concentrate, such as tankage, wheat middlings, linseed meal, pea meal, or soybean meal.

Corn alone vs. corn and nitrogenous supplement for pigs

Average ration	Initial weight Lbs.	Daily gain Lbs.	Feed for 100 lbs. gain Lbs.
Lot I, total of 180 pigs			
Corn, 4.8 lbs.	115	0.9	602
Lot II, total of 187 pigs			
Corn, 4.3 lbs. Supplement, 1.4 lbs.	117	1.3	441

Altho most of these pigs were well grown when placed on trial, averaging over 100 lbs. in weight, Lot II, fed corn and a nitrogenous supplement, made over 40 per ct. larger gains and required 27 per ct. less feed for 100 lbs. gain. Had they been younger at the beginning of the trials those fed corn only would have done even poorer. These trials show that one cannot afford to feed corn alone to growing, fattening pigs. Corn alone gives fair results for fattening mature sows, but even here the use of a supplement is advisable. As has been shown in the previous chapter, for brood sows it is highly important that feeds rich in protein and lime be fed with corn.

In the corn belt corn is usually fed on the cob. This is a wise practice, for as we have seen in the previous chapter, there is no appreciable advantage in shelling, grinding, or soaking corn for pigs under 150 lbs. in weight, and it is doubtful whether even for older ones the slight saving will pay for such preparation. Pigs do better on ear corn than on corn-and-cob meal, for their digestive organs can not well utilize a hard, fibrous material like corn cobs, even when ground.

Hogging down corn.—In the corn belt many farmers turn pigs into fields of standing corn, in which rape or other supplemental crops have usually been sown, and let them do their own harvesting. In three trials at the Minnesota[1] and Iowa[2] Stations this "hogging down" system was compared with feeding ear corn in a yard, either wheat middlings or tankage being fed to all lots in addition. The pigs hogging down corn in which rape or rye had been sown at the last cultivation made larger gains and required 10 per ct. less concentrates for 100 lbs. gain than those fed ear corn in the yard.

In tests at the Iowa Station rape was grown in the corn field at an additional cost of only $0.40 per acre, rape and pumpkins at $1.00, rye, soybeans, or cowpeas at $3.33, field peas at $3.60, and hairy vetch at $6.00 per acre. Feeding some protein-rich concentrate, such as skim milk, tankage, wheat middlings, or linseed meal, is always desirable, and is especially important when no supplemental crops have been grown in the corn field. Spring shotes, well grown on pasture and forage crops, are generally used for hogging down. Provided the ground is not muddy, pigs hogging down corn pick it up as closely as is usually done in husking. The pigs should be confined to limited areas by fencing, so that they will clean up each area in 20, or better, in 14 days.

The other cereals.—In Europe *barley* is the most esteemed cereal for the production of high quality bacon and in this country is important as a feed for pigs in the western states. In 6 trials at western stations pigs fed ground barley and wheat middings made slightly smaller gains than others fed ground corn and middlings, and required 10 per ct. more feed for 100 lbs. gain.

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[1] Gaumnitz, Wilson, and Bassett, Minn. Bul. 104.

[2] Evvard, Iowa Bul. 143.

Wheat is slightly superior to corn for fattening pigs[3] but when of good quality it is usually too expensive to be fed to stock. Grain which is damaged in quality and is not suited for milling may be worth nearly as much as sound grain for pig feeding.

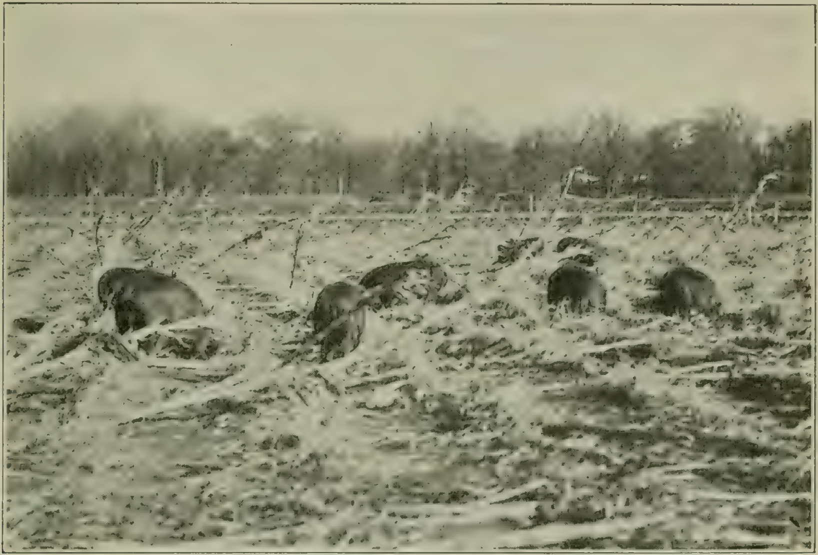

FIG. 102.—FATTENING PIGS HOGGING DOWN CORN

Pigs hogging down corn in which rape or other supplemental crops have been sown make larger and cheaper gains than those fed ear corn in a dry lot. (From Evvard, Iowa Station.)

Rye meal ranks a little below corn meal and is about equal to barley meal as a feed for pigs.

Oats are too bulky to serve as the only grain for fattening pigs and are usually costly compared with other cereals. In trials by the senior author[4] one-third oats and two-thirds corn gave better results than two-thirds oats and one-third corn. Toward the close of the fattening period but little oats should be fed. For brood sows oats are excellent, and for little pigs nothing excels ground oats with the hulls sifted out.

Emmer is also too bulky to give the best results when fed as the only grain to fattening pigs. A mixture of emmer and corn, however, gave nearly as good results as corn alone in a trial at the Nebraska Station,[5] both lots getting alfalfa hay in addition to the grain.

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[3] Weaver, Mo. Bul. 136; Eastwood, Ohio Bul. 268.

[4] Wis. Rpt. 1889.

The *grain sorghums* are of great importance for pork production thruout the western plains states. In trials at the Kansas Station[6] pigs fed ground milo or kafir with wheat shorts and tankage made nearly as large gains as others fed corn, shorts and tankage, and required only 2 to 5 per ct. more feed for 100 lbs. gain. Feterita and kaoliang ranked somewhat below kafir or milo, and sorgho grain was still less valuable, being rather unpalatable.

Seed from *hog* or *broom-corn millet* is satisfactory for pigs when ground and mixed with other feeds. At the South Dakota Station[7] pigs fed millet meal required 20 per ct. more feed for 100 lbs. gain than others fed barley meal.

As we have seen in the previous chapter, it pays to grind all the smaller cereals for pigs, tho sometimes it is advisable to scatter whole oats thinly on the ground or a feeding floor to force brood sows to exercise. Barley, wheat, rye, and the grain sorghums are all low in protein and, like corn, should be fed with protein-rich feeds, such as skim milk, tankage, wheat middlings, linseed meal, and soybeans.

Hominy feed.—In trials at the Indiana[8] and Ohio[9] Stations hominy feed was slightly superior to corn for pigs. On the other hand in recent trials by Evvard at the Iowa Station hominy feed was worth slightly less than corn. Probably hominy feed from which the oil has not been expressed, and which contains the corn germs is fully equal to corn.

Garbage.—Kitchen waste may be fed to swine, but care must be taken that dishwater containing lye or washing soda, broken dishes, etc., which are apt to cause death, be kept apart from the materials having food value. As there is likewise danger of poisons resulting from the decay of the garbage, the material should be thoroly cooked in all doubtful cases.

II. PROTEIN-RICH CONCENTRATES

Skim milk and buttermilk.—Rich in digestible protein and high in mineral matter, especially calcium and phosphorus, skim milk and buttermilk are ideal supplements to the cereals. Indeed, where skim milk or buttermilk is used as a supplement to corn or other cereals for growing, fattening pigs, the gains will usually be slightly larger than where other protein-rich feeds, such as tankage, wheat middlings, linseed meal, or soybean meal, are fed as supplements. These dairy by-products are especially valuable for young pigs after weaning and also for brood sows. If no water has been added, buttermilk is fully equal to skim milk for pig feeding.

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[5] Burnett and Snyder, Nebr. Bul. 99.

[6] Waters, Kinzer, Wright, and King, Kan. Bul. 192; Cochel, Kansas Industrialist, May 1, 1915.

[7] Wilson and Skinner, S. D. Bul. 83.

[8] Skinner and King, Ind. Bul. 158.

[9] Eastwood, Ohio Bul. 268.

It has been emphasized before that skim milk, buttermilk, or whey should always be pasteurized at the creamery or cheese factory before being returned to the farm, in order to prevent the spread of disease, especially tuberculosis, to which pigs are particularly susceptible.

Proper proportion of milk to grain.—Skim milk and buttermilk are too watery and also too rich in protein to produce economical gains when fed alone. They should therefore always be fed with the cereals or such carbonaceous concentrates as hominy feed. The proportion of skim milk or buttermilk to be fed with corn or other grain will depend first on the age of the pigs and next on the relative price of the feeds. After sufficient milk has been supplied to balance the ration, any addition will not increase the rate of gain and may even lower it if too much is fed.

Just after weaning 4 to 6 lbs. of skim milk to each pound of corn will be sufficient to make maximum gains with pigs in a dry lot. As they grow older the proportion of skim milk or buttermilk needed to balance the ration decreases as follows: Pigs weighing 50–100 lbs., 3 lbs. milk to 1 lb. corn; pigs weighing 100–150 lbs., 2–2.5 lbs. milk to 1 lb. corn; pigs weighing 150–200 lbs. or over, 1.5–2.0 lbs. or less. (See Appendix Table V.) Pigs on such pasture as alfalfa, clover, or rape need less milk to balance the ration.

Considerably more milk may be fed than is here stated with satisfactory results when a surplus is at hand; tho it will not have so high a value per 100 lbs. as when only sufficient is fed to balance the ration. This is shown in trials by the senior author at the Wisconsin Station[10] in which a total of 88 pigs, usually weighing 100 lbs. or over, were fed different proportions of skim milk and corn meal. When 1 to 3 lbs. of skim milk was fed to 1 lb. of corn, 327 lbs. of milk saved 100 lbs. of corn. However, with 3 to 5 lbs. of milk for each pound of corn it required 446 lbs. of milk to save 100 lbs. of corn; and with 5 to 7 lbs. of milk per pound of corn, 574 lbs.

Money value of skim milk.—In recent trials at the Wisconsin Station[10a] skim milk has been compared with tankage as a supplement to corn or barley, since tankage is about the best commercial substitute for skim milk. When just enough skim milk was fed to balance the ration, 100 lbs. of skim milk was worth one-half as much as a bushel of shelled corn, with corn at prices since the World War. When more skim milk is fed than is needed to balance the ration, the additional amount will be worth only about half as much, as the pigs use this extra amount not for the formation of protein tissues, but merely for making fat, thus wasting the nitrogen of the protein in the skim milk. For developing superior breeding stock skim milk has even a higher value than for producing pork.

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[10] Wis. Rpt. 1895.

[10a] Morrison and Bohstedt, unpublished data.

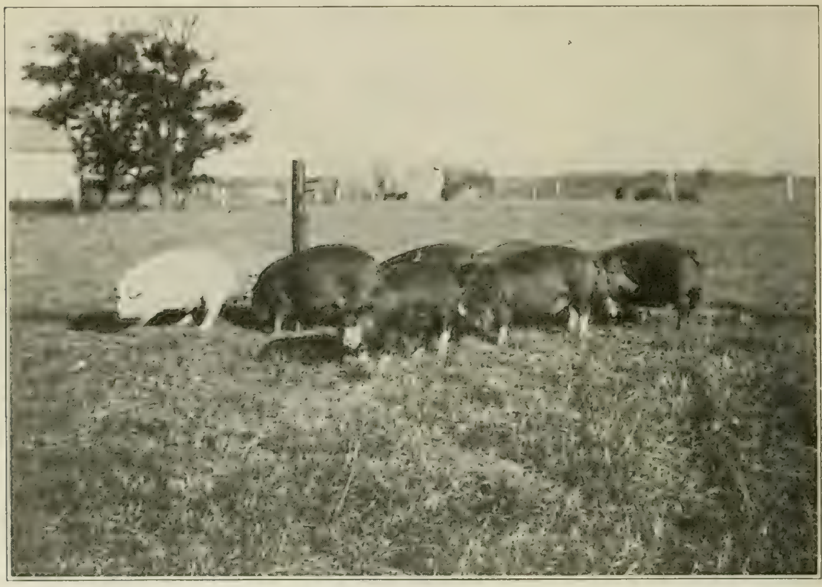

FIG. 103.—PIGS SELF-FED CORN AND TANKAGE ON ALFALFA PASTURE

On such a combination of feeds, growing pigs make large and economical gains. Even on alfalfa pasture, it is advisable to feed tankage or some other supplement with shelled corn. (From Wisconsin Station.)

Whey.—Whey such as is obtained from American cheddar cheese factories contains only a fair amount of protein, having a nutritive ratio of 1:6.8. However, the protein it does contain is admirably suited to balance the deficiencies of the proteins of the cereal grains. For this reason pigs over 150 lbs. will make good gains on only whey and corn or barley.[10b] Younger pigs should be fed protein-rich feeds, such as tankage or linseed meal, in addition. Whey is worth about half as much per 100 lbs. as skim milk. Skimming whey does not materially reduce its feeding value. Slightly sour whey has as high value as sweet whey, but it must not be allowed to putrefy.

[10b] Morrison and Bohstedt, Wisconsin Station, unpublished data.

Tankage; meat meal.—The value of tankage or meat meal as a supplement to corn and other carbonaceous concentrates has been demonstrated in trials at many stations and by experience on many farms. Rich in protein which is well-balanced in composition, and likewise high in calcium and phosphorus, tankage is excelled only by skim milk and buttermilk in producing thrifty growth and large gains. Since tankage or meat meal for stock feeding is thoroly cooked under pressure at a high temperature, there is no danger of spreading disease by its use.

Trials at various stations show that when highgrade tankage, carrying 55 per ct. of protein or over, is fed as the sole supplement to corn to pigs over 100 lbs. in weight, not over 9 to 10 per ct. is needed to balance the ration. With mature pigs even less tankage need be fed. With young pigs soon after weaning it is advisable to feed as high as 20 per ct. of tankage, or better, 9 to 10 per ct. of tankage and sufficient linseed meal, wheat middlings, etc., to provide the proper amount of protein for animals of this age. Where a lower grade of tankage is fed, the amount supplied should be correspondingly increased. For pigs fed corn on such protein-rich pasture as alfalfa, clover, soybean, cowpea, or rape, 5 per ct. of high grade tankage is enough to balance the ration for pigs 100 lbs. in weight or over. When pigs are following steers being fattened chiefly on corn, it will pay to feed the pigs one-fourth to one-third pound of tankage per head daily.

Wheat by-products.—*Wheat middlings*, or *shorts*, are a popular protein-rich supplement for pigs. They are fairly rich in protein and are high in phosphorus, but are relatively low in lime. Recent trials by Morrison and Bohstedt at the Wisconsin Station show that middlings are not a satisfactory supplement when fed with corn, barley, or other grain to pigs not on pasture. Pigs so fed usually make low gains, probably due to the poorly balanced nature of the proteins that such a ration furnishes. However, satisfactory results are secured where middlings are used as a supplement to the cereals for pigs on pasture or where they are used along with tankage or dairy by-products, which contain proteins which balance the deficiencies of the proteins in the cereals and middlings. While pigs not on pasture will make considerably larger gains if fed corn and tankage than if fed corn and middlings, a combination of the three feeds excels even corn and tankage.

Red dog flour and *flour wheat middlings* are worth somewhat more than standard middlings, as they contain more protein and also over 10 per ct. more total digestible nutrients. Red dog flour is especially useful for quite young pigs, which need a highly digestible, palatable feed containing little fiber.

Wheat bran is too bulky to be fed in large amounts to fattening pigs, middlings being far preferable. Where clover or alfalfa hay, roots, or other cheap bulky feed are not available, a limited amount of bran is excellent for brood sows, as it is bulky and also laxative.

Linseed meal.—Linseed meal is commonly used, especially in the northern states, as a supplement for swine. It gives excellent results as a supplement to the cereals when fed to pigs on pasture or if used along with tankage or dairy by-products. Recent trials by Morrison and Bohstedt at the Wisconsin Station show, however, that linseed meal is not a satisfactory supplement when fed with corn, barley, or other cereals to pigs not on pasture, probably due to the fact that the proteins of such a ration are unbalanced in composition. Especially for brood sows, it is often highly beneficial to add a small amount of linseed meal to the ration on account of its laxative effect.

Other protein-rich concentrates.—*Cottonseed meal*, as now prepared, is poisonous to swine, and no uniformly successful method of feeding it has yet been found, tho a few feeders, guided by experience, use it with little loss. If cottonseed meal is not fed continuously for over 40 days and does not form over one-fourth of the ration, and if the pigs are freely supplied with green forage or graze on pasture, the risk is slight. It is considered safe to have pigs follow steers which are being fed cottonseed meal, for the meal does not seem to be poisonous after passing thru the cattle. One should see that the steers do not throw so much meal out of the feed boxes that the pigs may be poisoned by eating it.

Field peas, rich in protein, are well suited to supplement corn and the other cereals. In certain irrigated mountain valleys of the West large numbers of pigs are fattened by turning them into fields of peas, or peas grown with oats or barley, after they have matured, an acre of good peas producing about 400 lbs. of gain.

Pigs fed *soybeans* and corn made slightly larger gains than others fed linseed meal and corn at the Indiana Station,[11] and required somewhat less feed for 100 lbs. of gain. No more soybeans should be fed than is needed to balance the ration, for when fed in large amount they produce soft pork, dark in color. They are commonly ground for pigs.

Cowpeas are of great importance in the South for economical pork production. The seed may be used as a supplement to corn or other carbonaceous feeds, or the pigs may be turned in to harvest the crop when the pods are well matured.

Peanuts, likewise of great importance for pork production in the South, are commonly harvested by letting the pigs gather the crop. Peanuts alone produce soft pork, but this may be overcome by feeding corn during the last part of the finishing period. Peanuts can be grazed during only a relatively short season, for after a time the nuts sprout or rot if left in the ground, especially in wet weather.

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[11] Skinner and Cochel, Ind. Buls. 126, 137.

Gluten meal and *gluten feed* give satisfactory results when fed with corn and some other supplement, such as skim milk, tankage, or linseed meal. It is not advisable, however, to use these corn by-products as the sole supplement to corn for pigs in the dry lot, for the pigs then receive only corn protein, which, as we have seen in Chapter IX, is somewhat unbalanced in composition.

Rice bran and *rice polish* are economical feeds for pigs in the rice-growing districts of the South, 100 lbs. of rice polish being equal to 133 lbs. of corn, and 100 lbs. of rice bran equalling 112 lbs. of corn.[12]

III. Forage Crops, Pasture, and Other Succulent Feed; Hay

Value of forage crops and pasture.—Thru the use of suitable forage and pasture crops, pork may be produced at a much lower cost than where pigs are maintained in dry lots on expensive concentrates alone. Spring pigs will thrive amazingly on good pasture supplemented by a limited allowance of concentrates and if not finished by the close of the pasture season will be in condition to make most economical gains in the dry lot. Not only do pigs at pasture make cheaper gains, but the succulent feed and the exercise they obtain aid in keeping them thrifty and healthy. When pigs are fed in dry lots it is difficult to save the manure unless they are confined closely, and thus much fertility is wasted. With pigs at pasture the manure is uniformly distributed on the fields. By using forage crops thruout the growing season and legume hay during the winter the cost of maintaining brood sows may be materially reduced. Tho pasturage is of prime value for pigs in all sections of the country, it is especially important in the southern states, where, by a well-selected rotation of pastures, green feed may be furnished nearly the entire year.

As Evvard of the Iowa Station[13] writes: An ideal forage for hogs should show: (1) adaptability to local soil and climate; (2) palatability; (3) a heavy yield of digestible nutrients, being high in protein and mineral matter, especially calcium and phosphorus, and low in crude fiber; (4) succulence; (5) long pasturing season; (6) ability to endure grazing; (7) permanency; (8) reasonable cost and ease of seeding; (9) capability of furnishing quick pasture at any time during the growing season. "These essentials are not found in any single forage, but alfalfa, the clovers, and rape have most of them."

Amount of grain to feed on pasture.—Owing to the high price of concentrates, it is a question of prime importance to find how much of them should be fed to pigs on pasture. It is never profitable to force young pigs to live on pasture alone, for even on the best alfalfa, clover, or rape pasture they barely maintain their weight. Except in districts of the West where alfalfa is abundant and grain unusually high in price, it is usually most profitable to feed 2 lbs. or more of corn daily per 100 lbs. of pigs than to feed less, even when the pigs are on good pasture. Full-grown brood sows not suckling pigs will fatten with less grain while on pasture than will growing pigs.

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[12] Dvorachek, Arkansas Sta., information to the authors.

[13] Iowa Bul. 136.

FIG. 104.—ALFALFA EXCELS AS A PASTURE FOR PIGS

Where alfalfa thrives, it is the best permanent pasture for pigs, on account of the rapid gains it will produce and the large number of pigs it will carry per acre. (From *The Field.*)

Alfalfa pasture.—Wherever it thrives alfalfa is the best permanent pasture crop for pigs, as these animals do not bloat. It provides pasturage during a longer season than any other single crop, starting early in the spring and remaining green and succulent in late summer when bluegrass has dried up and even clover grows hard and woody. Since the heavy pasturing of alfalfa is injurious to the stand, the number of pigs should be restricted and the plants allowed to grow up, being cut for hay 2 or 3 times a year. In tests at the Iowa Station by Evvard and Kennedy [14] in which pigs were fed corn and tankage on alfalfa pasture the alfalfa produced 623 to 865 lbs. of pork per acre, after deducting the gains to be credited to the concentrates fed, and without crediting the alfalfa with the hay cut from the pasture. In one trial an acre of alfalfa, supplemented by corn and tankage, carried an average of over 16 spring pigs for 180 days, producing 1.05 lbs. of gain per head daily. In addition nearly 2 tons of hay was cut per acre from the plot during the season.

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[14] Iowa Bul. 136.

Pigs fed corn alone on alfalfa pasture make fairly satisfactory gains, since the alfalfa goes far toward balancing the corn. More rapid gains are, however, secured when some supplement is fed, 5 lbs. of tankage to 95 lbs. of corn (or an equivalent amount of other supplements) being sufficient for pigs weighing 100 lbs. or over.

Clover pasture.—In the northern and central states *red clover* is one of the most valuable pasture crops for pigs, being surpassed only by alfalfa and perhaps by rape. Since early pasturing may kill clover, pigs should not be turned on until it has made a good growth. Clover does not furnish as constant a supply of succulent feed as does alfalfa, tending to become woody late in the summer, but clipping will greatly aid in inducing a new growth. On soils too wet or too acid for red clover *alsike clover* may be grown. Especially in the southeastern states *crimson clover*, sown as a winter annual, furnishes valuable spring pasture for pigs.

On soils not well adapted to alfalfa or red clover, *sweet clover* may often be used to advantage as a pasture for pigs. The first year's growth is best suited to pigs, as it is less coarse and woody. To encourage the growth of new shoots the crop should be pastured reasonably close and the tall growth clipped with a mower.

Rape pasture.—Over the greater part of the northern United States rape is a most excellent annual forage crop for swine. As it may be sown both early and late in the season, forage may be provided at any desired time. The best yields are usually obtained with spring seeding and if the crop is not pastured too closely growth will continue until fall. Pigs should not be turned on the rape until it is 10 to 14 inches high and when it is pastured down to 4 or 5 leaves to the plant the animals should be transferred to another plot to give the crop a chance to recover, or preferably, fewer pigs should be pastured per acre. On good soil an acre of rape should furnish grazing for 16 to 20 pigs or even more thruout the entire season. Trials at the Wisconsin Station [14a] show that in the northern states a mixture of oats, field peas, and rape is slightly better than rape alone.

In 6 trials at corn-belt stations in which rape pasture was compared with alfalfa, the pigs on rape pasture made practically as large average gains as those on alfalfa pasture and required only 340 lbs. of concentrates per 100 lbs. of gain, which was slightly less than the pigs on alfalfa required. Where alfalfa thrives, it surpasses rape, chiefly because it need not be reseeded each year and also because it is a legume and thus builds up the soil. Evvard of the Iowa Station[15] found that the portion of the rape plant eaten by pigs is nearly as rich in protein, on the dry matter basis, as is alfalfa, and that 5 lbs. of tankage (or an equivalent amount of other supplements) to 95 lbs. of corn is enough for pigs weighing 100 lbs. or over, when on good rape pasture.

[14a] Morrison and Bohstedt, unpublished data.

FIG. 105.—RAPE IS ONE OF THE BEST ANNUAL CROPS FOR PIGS

Over most of the northern states, rape is the best annual forage crop for pigs, furnishing excellent pasture from early summer till late in the fall. (From Wisconsin Station.)

Other pasture crops.—*Field peas,* sown either alone or with oats or oats and rape, are a most satisfactory summer forage crop for pigs in the North. As has already been mentioned, large numbers of pigs are fattened on field peas in certain districts of the West.

Soybean pasture in the North is surpassed by alfalfa, clover, rape, and field peas, except perhaps on light, sandy soil, where the soybean may produce a larger crop. In the South, however, the soybean is one of the best allies of the pork producer. In three trials at the Alabama Station[16] the feed cost of 100 lbs. gain by pigs fed corn

[15] Iowa Bul. 136.

[16] Gray, Ridgeway, and Eudaly, Ala. Bul. 154.

meal on soybean pasture was only $2.59 to $3.36, with corn at 70 cents per bushel and soybean pasture at $8 per acre. Soybeans are often grown with corn and the combined crop hogged down.

Especially on poorer soils in the southern states, the *cowpea* is an important forage crop for swine, as it flourishes where other legumes will not produce good crops. Cowpeas are excelled by soybeans where the latter thrive, as they yield more seed. Like soybeans, cowpeas and corn are frequently hogged down.

As has been already mentioned, *peanuts* are an important crop for fall feeding in the South. *Velvet beans* furnish excellent pasture for pigs in the extreme South where they thrive.

Among the permanent grasses, *bluegrass* provides the best pasture thruout the northern states. As bluegrass makes little growth during mid-summer, other crops should be provided for this season, the bluegrass being relied on for grazing in spring and early summer and again in early fall. With pigs fed corn on bluegrass, a somewhat larger allowance of protein-rich supplements is needed than on legume or rape pasture, tho very young bluegrass is fairly rich in protein. In the South, *Bermuda grass* furnishes the best permanent grass pasture for pigs.

Wheat, rye, oats, and *barley* are unexcelled for fall and early spring pasture in the North and for pasture from late fall thruout the winter and spring in the South. *Winter rye* and winter oats will furnish pasture thruout the entire winter in the South, greatly decreasing the cost of maintaining brood sows and raising fall pigs.

Ripe grain, usually rye, bald barley, or wheat, is frequently hogged down, the pigs being turned into the field when the crop is nearly ripe. This practice is especially common in the grain districts of the Pacific Northwest, where the summers are dry. It is doubtful whether it is generally profitable to hog down the small grains in the humid districts, if labor can be secured to harvest the crop.

Especially on grain farms of the West, *stubble fields* are an important factor in economical pork production. Where the grain is harvested by the header, considerable is left ungarnered and this was formerly wasted; now many farmers are hog fencing their fields and turning pigs on the stubble to glean the scattered heads of grain. Gains made on such waste are almost clear profit.

Roots.—We have seen in previous chapters that for cattle and sheep silage from corn and the sorghums is about as satisfactory a succulent feed as roots, and usually costs much less. With pigs, however, silage will not replace roots, for they can not utilize large amounts of such coarse, fibrous feeds as silage. The value of roots for pig feeding is well shown by the average results from 8 trials at various stations, in which the pigs in one lot were fed an average of 5.4 lbs. of concentrates per head daily and those in a second lot 3.6 lbs. of concentrates and 5.6 lbs. of roots. The pigs given no roots required 499 lbs. of concentrates for 100 lbs. of gain, while those fed roots in addition required only 358 lbs. of concentrates and 631 lbs. of roots. In these trials each 448 lbs. of roots saved 100 lbs. of concentrates. With the high prices now ruling for concentrates, many farmers can profitably grow roots for winter succulence for their pigs. Danish farmers grow no Indian corn, and yet, by means of waste products of the dairy, purchased feeding stuffs, and root crops, mostly beets, they lead the world in the production of pork, both as to quality and also as to quantity, considering the area of the country.

Roots not only add variety to the ration but reduce the amount of concentrates required, and aid in maintaining the health of the animals. On account of their slightly laxative effect and their bulkiness, roots are valued by many breeders as a feed for brood sows. They will not, however, take the place of legume hay, as they are not rich in protein or lime. Roots are also valued for young pigs, but in finishing pigs the allowance of roots should be reduced, or the desired finish will not be secured. Where climate permits, pigs may be turned into a field of roots in the fall to gather the crop.

The relative feeding value of the various root crops depends on the amount of dry matter they yield per acre in any particular locality. According to Day,[17] sugar beets are most readily eaten by pigs, mangels ranking second in palatability.

Potatoes should be cooked for pigs and fed with concentrates, protein-rich feeds being included in the ration. In various trials 340 to 442 lbs. of potatoes have saved 100 lbs. of grain.

Sweet potatoes are an excellent root crop for fall and early winter feeding in the South, especially for the cut-over pine lands. Planted in June and early July, they are ready for feeding by the middle of October. Since the tubers are low in protein, pigs grazing sweet potatoes should be given such feeds as soybeans or cowpeas.

Silage.—Clover, alfalfa, or other legume hay is generally more satisfactory for pigs than silage of any kind. Corn silage is too woody and too low in digestible matter to be valuable for swine. If shotes and breeding stock live on a limited allowance of rich concentrates alone, they may suffer from lack of proper bulk in the ration. In such cases, if roots or legume hay are not available, even corn silage will be helpful in distending the digestive tract.

The legume hays.—With the prices of feeding stuffs ruling high, the swine feeder must make the largest possible use of alfalfa, clover, vetch, cowpea, soybean, and other legume pasture in summer, and in winter feed freely of well cured hay from the legumes, in order to have healthy animals and to keep down the cost of production. The finer parts of clover and alfalfa hay, especially the first cutting of clover and the last cutting of alfalfa, are often as valuable for feeding pigs as is the same weight of expensive wheat middlings. The southern planter has a specially choice list of equally valuable legumes including hay from cowpeas, soybeans, peanuts, etc. Legume hay may be fed to pigs from slatted racks or from boxes with openings low on the sides from which the animals can eat at will. The legume hays not only furnish protein, so essential for building all the lean meat tissues and the organs of the body, but they also carry much calcium (lime), which is needed in bone building. They are therefore doubly useful in supplementing Indian corn and the other cereals, which are rather poor in both protein and calcium.

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[17] Productive Swine Husbandry, p. 206.

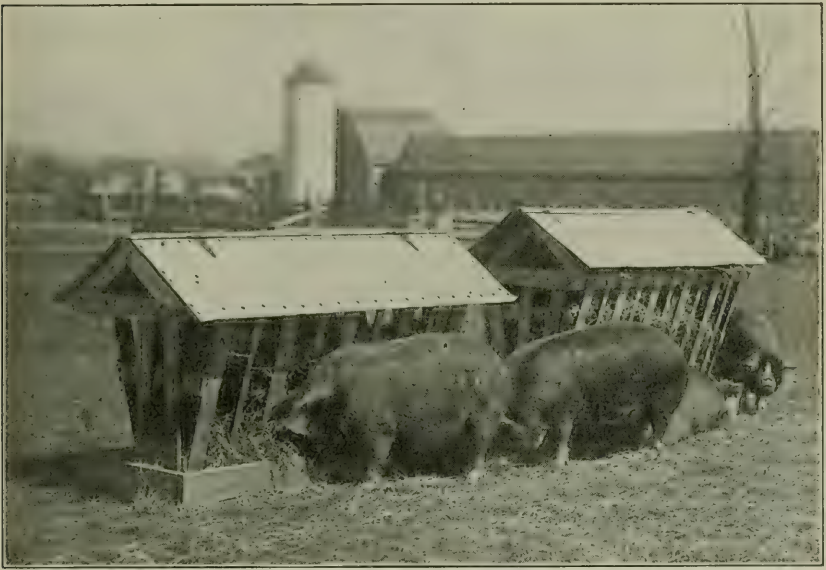

FIG. 106.—BROOD SOWS EATING ALFALFA HAY FROM RACKS

Fine, well-cured legume hay should be provided for all brood sows and may often be used with profit for other pigs. (From *Breeder's Gazette.*)

Leafy, bright *alfalfa hay* is the best of all hays for the pig. Not only is this hay useful for brood sows and stock pigs but it is a cheap and fairly efficient supplement to corn or the other cereals for fattening pigs. While fattening cattle and sheep will consume enough alfalfa hay to make a fairly well balanced ration with corn, the fattening pig has not this capacity for roughage, and hence will not consume enough hay to balance his ration sufficiently to produce maximum gains. For example, in trials at the Kansas Station[18] pigs fed a ration of 6.6 lbs. of corn and 0.9 lb. tankage gained 1.58 lbs. per head daily, while others fed 6.5 lbs. corn and 1.2 lbs. alfalfa hay in a rack gained only 1.13 lbs. With corn at $19, alfalfa hay at $8, and tankage at $41 to $45 per ton, the pigs fed tankage made cheaper gains than those fed alfalfa hay.

On the other hand, with corn and barley at $20, tankage at $40, and alfalfa hay at $5 per ton, the Colorado Station[19] found alfalfa a much more economical supplement than tankage. Whether to use alfalfa hay or purchased concentrates to balance the ration of fattening pigs will therefore depend on the relative price of these feeds. Alfalfa hay is most efficient as a supplement in fine winter weather when the pigs have good appetites for the hay and corn. In unfavorable weather or when the pigs are out of condition the use of some nitrogenous concentrate, like tankage, linseed meal, or shorts, aids in stimulating the appetite and hence results in larger gains.

QUESTIONS

1. Give the results of feeding trials in which corn has been fed alone and with a supplement to pigs.
2. Discuss the hogging down of corn.
3. What is the value for pigs of wheat, rye, oats, emmer, the grain sorghums, millet, hominy feed?
4. What is the best supplement to corn from the standpoint of gains produced?
5. How much skim milk would you feed per pound of corn to pigs of various weights?
6. What is the value of buttermilk and whey for pigs?
7. How much tankage is needed to balance the ration of corn-fed pigs?
8. Discuss the value for pigs of the other protein-rich concentrates fed to swine in your locality.
9. Name 9 essentials of a good forage crop for pigs.
10. What are the best forage crops for swine in your locality, and why are they the best?
11. Discuss the value of roots and of silage for swine.
12. How may legume hay be used in swine feeding?

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[18] Waters and Kinzer, Kan. Bul. 192.

[19] Morton, Colo. Bul. 188.

CHAPTER XXIX

FEEDING AND CARE OF POULTRY

Poultry husbandry is a generalized rather than a specialized industry, for no other class of live stock is kept so widely, yet relatively few rely upon poultry raising for their main income. Both on the farm and on the city lot poultry consume much waste material, converting it into highly nutritious and palatable eggs and meat. On the farm, poultry occupy a distinctive place, for a fair-sized flock may be kept to a considerable extent on land occupied by crops. Here they will not only gain much free food, but they will also benefit the crops by devouring injurious bugs, grubs, and worms. They are largely cared for by the women and children, and thus do not compete for labor with other lines of farming. General conditions are highly favorable for the farm flock of moderate size, even tho the feeding and care often receive little attention. Range is abundant, numerous buildings and trees provide protection from sun and wind, and epidemics of disease are much less serious than where large numbers of birds are kept under intensive conditions. It is due to these advantages of the farm flock that most of the spectacular, large scale poultry enterprises have failed.

FIG. 107.—A BROOD OF PROFIT MAKERS

Chicks make use of many waste products and may be easily raised on the farm or on a city lot. (From Halpin, Wisconsin, Station.)

In the economy with which she produces human food, the hen ranks next to the pig, as is shown in Chapter V. She returns 5.1 lbs. of edible solids (water-free) in eggs or 4.2 lbs. in meat from 100 lbs. of digestible matter in her ration. When poultry are kept as a side-line, their economic efficiency is really greater than these figures indicate, because a large part of their food is material that would otherwise be wasted.

Importance of poultry.—Under the term poultry are included fowls, turkeys, ducks, geese, swan, guineas, pigeons, peafowl, and pheasants.

In aggregate value the annual yield of poultry and eggs in the United States amounts to $750,000,000, exceeding the value of all the gold, silver, iron, and coal mined annually in this country. According to the Census of 1910, over 88 per ct. of all the farms reported flocks of poultry, the average farm income from poultry for these farms being $105, in addition to the eggs and meat consumed on the farm. The value of the eggs produced in this country amounts to about twice as much as the value of the meat.

Of the total number of poultry in the United States, about 95 per ct. are chickens, about 4 per ct. ducks, turkeys, and geese, and the remaining 1 per ct. guineas, pigeons, pheasants, and other domestic birds. Because of their importance, the following discussions deal almost entirely with chickens. The popularity of chickens is due to the fact that they are usually much better egg producers than the other species and that they, moreover, furnish a most convenient source of fresh meat on the farm.

The digestive system of poultry.—The digestive tract of poultry is quite different from those of the larger farm animals. Poultry have no teeth with which to chew their food, the teeth and lips being replaced by a horny mandible on each jaw, which forms the beak, or bill. Such soft feeds as vegetables, green herbage, or meat can be torn into pieces by the beak, but hard substances like grain are swallowed whole. Since no chewing is done in the mouth, abundant saliva is not needed and the salivary glands are imperfectly developed.

From the mouth the food is forced down the gullet into the crop, a pouch-like enlargement of the gullet just before it enters the body cavity. No enzymes are secreted in the crop, but the feed is softened as in the paunch of ruminants, such hard materials as grain remaining in the crop about 12 hours. From the crop the food passes thru the second part of the gullet into the glandular stomach, where the gastric juice is secreted. Passing thru the glandular stomach, the food, with the acid gastric juice, enters the gizzard, or muscular stomach. This is a powerful, muscular grinding apparatus, with a tough, horny lining, and in it the food is finely ground with the aid of small stones and grit. The gizzard has a truly remarkable grinding and crushing power, being able to bend pieces of iron and wear smooth the edges of pieces of broken glass.

From the gizzard the partially digested food passes into the small intestine, in which the digestive processes are similar to those in the other farm animals. The large intestine in poultry has but small capacity. It consists of a small rectum and two caeca, or blind guts, at the juncture of the small intestine and the rectum. A further peculiarity of poultry is that the urine and feces are not voided separately,

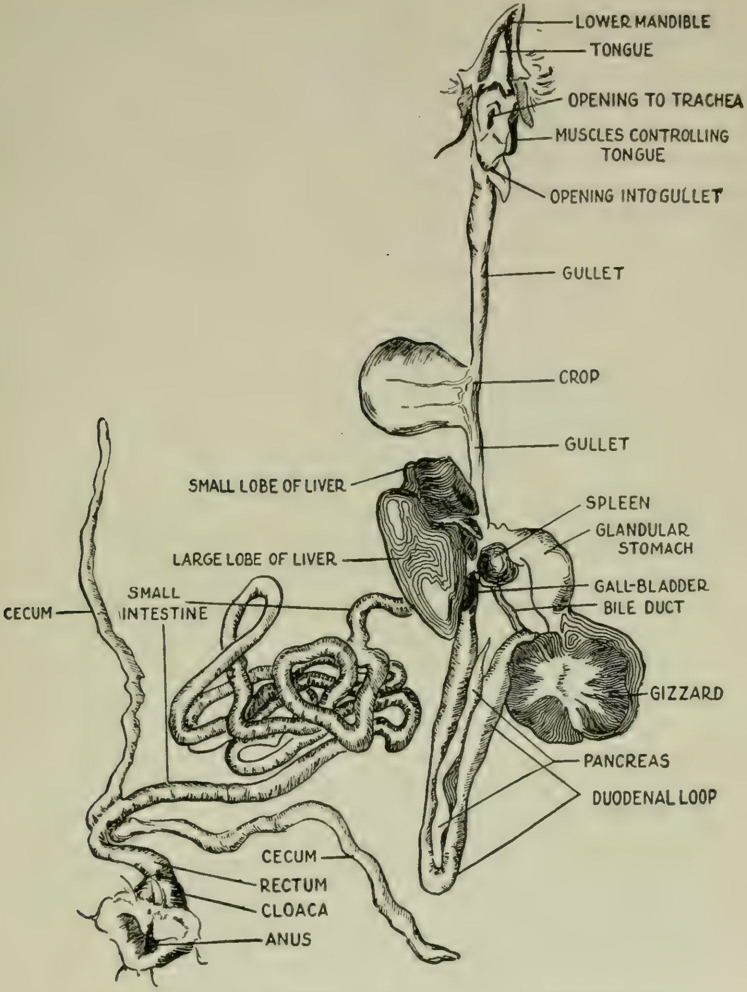

FIG. 108.—THE DIGESTIVE SYSTEM OF THE FOWL

The digestive system of the fowl differs in several respects from those of the larger farm animals. (From Lippincott, *Poultry Production.*)

but both are excreted thru a common chamber, the cloaca. Most of the water in the urine is reabsorbed in the cloaca, and the urine is voided as a whitish paste with the feces. The nitrogenous waste is excreted chiefly in the form of uric acid, instead of as urea, as with mammals.

Nowhere in the digestive tract of poultry does much digestion of crude fiber take place. The food remains in the crop too short a time for any appreciable digestion there thru bacterial action, such as occurs in the paunch of ruminants, and little bacterial action takes place in the large intestine. Due to this, crude fiber has little value for poultry, but serves simply to give bulk to the ration. Hence, the feed of poultry must be more concentrated in character than that for other farm stock.

Digestibility of feeds by poultry.—Since the urine is not voided separately by poultry, digestion trials can not be conducted satisfactorily in the same manner as with other animals. In general, the digestibility of feeds by poultry resembles that of swine, tho poultry digest even less fiber. The digestibility of grain for poultry is not increased by grinding, as all seeds are ground fine in the gizzard, if grit is available.

Feeding standards and nutrient requirements of poultry.—Owing to the fact that satisfactory digestion coefficients have not been obtained for poultry, our knowledge of their actual nutrient requirements is less definite than for other classes of stock. Wheeler of the New York (Geneva) Station[1] has presented the most complete standards which have yet been advanced. These, converted to the same terms as the Modified Wolff-Lehmann Standards, are given in Appendix Table V. It will be noted that poultry require a much larger amount of nutrients per 1,000 lbs. live weight than do the other farm animals. This is due to their small size and the consequent greater radiation of heat from the body, and to their high body temperature and great activity. No figures are given for the amount of total dry matter, but, as mentioned previously, on account of the nature of their digestive tract, rations for poultry must be more concentrated than for other stock, even swine.

The nutritive ratios recommended for growing chicks and for laying hens are narrower than for nearly all other classes of farm animals. This is because chicks and other young poultry grow very rapidly in proportion to their size and hence store large amounts of protein in their bodies. Laying hens require a narrow nutritive ratio because they are yielding a product very high in protein. Eggs contain about 65.9 per ct. water, 12.8 per ct. crude protein, 10.6 per ct. fat, and 10.7 per ct. mineral matter. The protein thus forms about 38 per ct. of the total dry matter. On account of these facts, rations for growing and laying poultry should contain a rather larger proportion of protein-rich feeds than for other farm animals. For fattening poultry less protein is needed and the nutritive ratio may range from about 1 : 6.2 for young birds which are still growing to 1 : 8 for mature poultry.

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[1] Jordan, The Feeding of Animals, pp. 393–5.

Mineral matter.—The shells of eggs, which comprise about 11 per ct. of their total weight, consist almost entirely of calcium carbonate (carbonate of lime). Laying hens must therefore have a supply of calcium in addition to that furnished in the grains and other common feeds. Trials by Halpin [2] at the Wisconsin Station show that calcium is as important as any other part of the ration. Hens produced but few eggs when fed rations excellent for egg production except that they were deficient in calcium. When plenty of calcium was supplied a normal yield of eggs was secured.

Oyster shells are the best form in which to supply calcium. They should be placed in hoppers or boxes in the poultry house so that the fowls can help themselves. *Clam shells,* sometimes used in place of oyster shells, are not considered as good. Growing chicks require an abundant supply of both calcium and phosphorus for the building of their skeletons and body tissues. Therefore, unless the feeding stuffs of the ration furnish an abundance of these mineral nutrients, they should be supplied by giving some form of bone. *Granulated bone* and *bone meal* are most commonly used. Green cut bone, discussed in the following chapter, furnishes both mineral matter and protein. Trials at the New York (Geneva) [3] and Rhode Island [4] Stations indicate that ground bone is a better source of these minerals than is rock phosphate.

Grit, or crushed rock, should also be supplied poultry to aid in the grinding of feed in the gizzard, unless they have access to plenty of coarse sand or fine gravel. Several kinds of rock are crushed for grit, the best form being a light-colored lime rock. Commercial grits are commonly furnished in chick size, medium, and large size.

Animal food.—Trials at various stations indicate that for the best results poultry should receive animal food of some kind. When given abundant range in summer they secure it in the form of bugs, grubs, and worms. Opportunity for range has a two-fold advantage, for in addition to the free animal food, the poultry destroy insects which would damage crops. Whenever the insect and worm supply runs short, one of the substitutes discussed in the following chapter should always be provided.

Salt; water.—Salt is needed by poultry as well as by other stock and therefore a small amount should be added to the mash. Wheeler [5] recommends 5 ounces per 100 lbs. of feed for mature stock but advises that young stock be given no salt until 2 months old.

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[2] Information to the authors.

[3] Wheeler, N. Y. (Geneva) Bul. 242.

[4] Hartwell and Kirkpatrick, R. I. Bul. 145.

[5] N. Y. (Geneva) Rpt. 26.

A constant supply of fresh, clean water is an essential for all classes of poultry. The watering arrangement should be so constructed that the birds will not roost upon it and foul the water with their droppings, and should be high enough to prevent litter being scratched into it. For chicks a vacuum fountain is desirable. The simplest form of such a fountain is simply a jar filled with water and inverted on a pan of water. As the chicks drink the water from the pan, air enters the jar and water flows out into the pan until the water level rises.

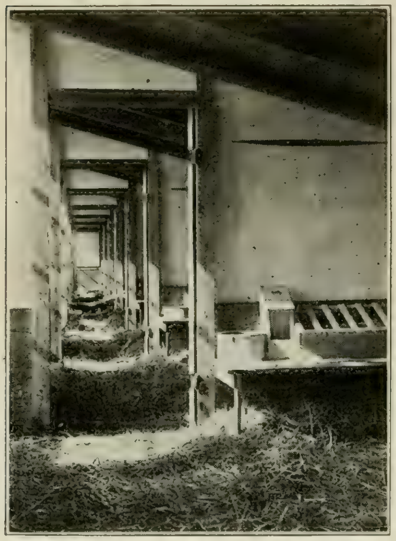

FIG. 109.—INTERIOR OF CONTINUOUS POULTRY HOUSE AT WISCONSIN STATION

This house is sunny, well-lighted, well-ventilated, dry, and free from drafts. Note the shelf on which stand water crock and self feeders for grit and dry mash. (From Halpin, Wisconsin Station.)

Charcoal and condiments.—A supply of charcoal, sold on the market as granulated charcoal, should be kept before poultry as it acts as a regulator of the digestive tract. The use of such condiments as pepper, ginger, and mustard is not to be recommended for poultry.

Shelter.—There is no need of building an elaborate, expensive house for poultry, but to be healthy and profitable the farm flock needs dry, well-ventilated, well-lighted quarters, free from drafts. Fowls have no sweat glands and suffer from too close and warm quarters even more than do other animals. It is important that the house be easy to disinfect. Hence, all the fixtures—nests, perches, coops for broody hens, feed hoppers, etc.—should be simple and removable. A dropping board below the perches is desirable. So that they will have plenty of room for exercise, at least 4 square feet of floor space should be allowed each hen, and 6 to 10 inches of roost space, depending on the size of the fowls. Ventilating systems, such as the King, which depend on the difference in weight between heated and cold air, do not work well in poultry houses, because there is too much cubic space per 100 lbs. live weight of fowls to warm the air enough. For ventilation, the poultryman must rely on having part of the windows protected only by muslin or by open slats, or left entirely open as in the "open front" house. The house should be well-bedded with straw which is renewed when it becomes damp or filthy. Two or three times a year the house and all fixtures should be thoroly disinfected.

The quarters should be located on well-drained soil, and preferably on a south slope, an east slope being next best. The site should have good air drainage and have ample range adjacent. Trees near the house provide summer shade and keep out the wind. Fowls also appreciate some low shrubbery nearby under which they may hide.

Poultry houses are of three types: (1) The portable colony house with a single pen, (2) the long, continuous house of two or more pens, and (3) the large, single-unit house. The permanent house has certain advantages for housing the flock in winter in the northern states, but on every farm where a good-sized flock is kept there should be at least one portable colony house. In this the young stock may be reared on the range and later the pullets be kept apart so that they will not be abused by the older fowls.

Preparation of feed; dry and wet mash.—It has been pointed out previously that grinding grain does not increase its digestibility for poultry. However, poultrymen have found it profitable to feed fowls about one-third of the ration ground in the form of a "mash," as this saves the birds considerable energy. The rest of the ration commonly consists of grain, fed whole, except in the case of corn, which is often cracked coarsely. The grain is usually thrown on the straw used for bedding the house, where the fowls must scratch to secure it, thus getting ample exercise. Feeding the mash dry in self-feeding hoppers saves labor and gives the best results except for fattening fowls, which may be induced to eat more if the mash is moistened and fed in a trough. It is well, for variety, to give all fowls a wet mash three times a week, perhaps made of the same feeds that make up the dry mash but moistened with water or milk. For chickens a wet mash should be crumbly and not sticky.

Green feeds.—Some green food is essential for the best results with poultry. The value of these feeds lies not so much in the nutrients they furnish as in the stimulating effect on the appetite and on the digestive tract. Where poultry have plenty of range, they will secure an abundance of green feed during the growing season. Successful poultrymen agree that provision should be made to continue the supply of green feed thruout the winter. Where little or no range is available in spring and summer, soilage or pasture crops should be specially grown.

Types of fowls.—Two classifications may be followed in grouping the various breeds of fowls: (1) the so-called "standard" classification of the American Poultry Association, which is based primarily upon the origin and distribution of the breeds, and (2) the utility classification, which is based upon the suitability of the breeds for the production of eggs and meat. According to the latter classification,[6] the breeds are grouped as follows: (1) egg breeds; (2) meat breeds; (3) general-purpose breeds; (4) fancy breeds.

The *egg breeds*, developed primarily for egg production, are small or medium-sized fowls, active, nervous and sprightly, slender in body, relatively long-legged, and early maturing. These breeds do best on ample range and show the least tendency to sit of any type. They may be compared to the dairy cow, the racing horse, and the fine-wooled sheep. Breeds of this type belong chiefly to the Mediterranean class, so named because they originated in Mediterranean countries. All lay eggs white in color. By far the most important breeds of this type in the United States are the Leghorns, followed by the Minorcas and Anconas.

The *meat breeds* are comparable to beef cattle, draft horses, mutton sheep, and lard hogs. They are relatively large in size, compact, thickly fleshed, wide of back and breast, and late maturing. The most important breeds of this type in the United States are the Brahmas and Cornish.

The *general-purpose breeds* are the most common on American farms. Midway between the other two types in shape and disposition, they yield good carcasses for the table and are fair to excellent layers. At the same time they make good mothers. This type includes both the American and the English classes. The most important breeds of the former are the Plymouth Rocks, the Wyandottes and the Rhode Island Reds; while the Orpingtons and Sussex are the most important representatives of the English class. The general-purpose breeds furnish by far the larger part of the poultry meat consumed in this country.

The *fancy breeds* include breeds and varieties kept mainly for exhibition purposes, such as the Polish, Bantams, Silkies, and Frizzles.

Feeding laying hens.—To secure a high egg production, it is essential that a complete, well-balanced ration, containing grain, mash, animal feed, green feed, shell, and grit, be fed. About 50 per ct. of the ration should be grain, 20 per ct. mash (not including animal feed sometimes mixed with the mash), 10 per ct. animal feed, 15 per ct. green feed, and 5 per ct. mineral feed. As in feeding other classes of stock, successful poultrymen differ quite widely in the exact routine followed in feeding.

Commonly a short time after the birds are off the perch in the morning a light feed of grain is scattered on the straw with which the pen is littered, and is well kicked in, to make the birds work in securing

[6] Lewis, Productive Poultry Husbandry, p. 78.

a meal. A heavy feed of grain is given on the litter two or three hours before the fowls go to roost, so that they will go on the perch with full crops. The birds should be examined occasionally after they have gone to roost to see whether they have enough grain. At night it is better to feed a little more than will be eaten than not to feed enough. However, the morning feed must be light enough so that the grain will be entirely cleaned out of the litter before the afternoon feeding.

The dry mash should be supplied in self-feeding hoppers, to which the fowls may be allowed free access at all times, except in the case of the meat breeds. As these tend to overeat, the hoppers should be kept closed during the forenoon. The green feed is commonly given at noon, as much being supplied as will be eaten in 20 to 30 minutes. For variety, it is well to feed a mash moistened with milk or water about three times a week in a trough. Fresh water should be given in the morning, at noon, and also at the afternoon feeding, except in cold weather.

In spring and summer plenty of range should be provided, if possible, so that the fowls will not only have plenty of green feed but may also secure most of the animal feed they need in the form of insects and worms. No special precaution need be taken then to enforce exercise, for the fowls will be busy all day hunting for choice morsels. On good range, the amount of additional animal feed supplied may be reduced materially. When ample range is not available, some of the green feeds discussed in the next chapter should be specially grown for the flock.

Good laying rations for winter.—As is shown in the following chapter, which discusses in detail all the important feeds used for poultry, the poultryman has chance for a wide selection in devising rations for his flock. From the available feeds he should choose those which will provide a well-balanced, satisfactory ration at least cost. Tho the particular combinations of feeds employed will differ widely in different sections of the country, the following rations, recommended by Halpin, will be suggestive, as they have all given good results.

Ration 1.—*Feed in deep litter* a mixture of 2 parts each by weight of corn and wheat and 1 part each of oats and barley (a light feed in the morning and a heavy one at night).

Feed in hopper (all the time) a mixture of 100 lbs. each of wheat bran, wheat middlings, and ground corn; 50 lbs. each of dry malt sprouts and meat scraps; and 2 lbs. of salt.

Feed in trough (3 times a week) the same mixture, moistened with milk.

Green feed—sprouted oats and mangels.

Grit, oyster shell, and *charcoal*, supplied in small boxes or grit hoppers.

Water—fresh and in abundance.

Ration 2.—*Feed in deep litter* a mixture of 2 parts each of corn and wheat and 1 of barley (a light feed in the morning and a heavy one at night).

Feed in hopper (all the time) crushed oats.

Feed in trough (3 times a week) a moist mash of equal parts bran and corn meal. Salt slightly.

Milk—sour milk or buttermilk to drink.

Green feed; grit; oyster shell; charcoal; and *water* as in Ration 1.

Ration 3.—*Feed in deep litter* a mixture of 2 parts each of corn and wheat and 1 of oats (a light feed in the morning and a heavy one at night).

Feed in hopper a mixture of 100 lbs. each of wheat bran, wheat middlings, corn meal, and meat scrap, with 2 lbs. salt. (Let the hens eat this when they wish.)

Green feed; grit; oyster shell; charcoal; and *water* as in Ration 1.

Ration 4.—*Feed in deep litter* a mixture of 4 parts corn, 2 parts wheat and 1 part oats (a light feed in the morning and a heavy one at night).

Feed in hopper a mixture of 200 lbs. wheat bran, 100 lbs. ground corn, 100 lbs. gluten feed, 75 lbs. oil meal, and 3 lbs. salt.

Feed in trough (3 times a week) the same mixture, moistened with milk.

Milk to drink, or add 50 lbs. meat scrap, or give meat scrap in small hopper, or give 3 ounces green bone to each hen per week.

Green feed; grit; oyster shell; and *charcoal* as in Ration 1.

Ration 5 (known as the Wisconsin simplicity ration).—*Feed in deep litter* only corn (a light feed in the morning and a heavy one at night).

Milk—sour milk before the flock at all times, no water.

Green feed; grit; oyster shells; and *charcoal* as in Ration 1.

On extremely cold days heat ear corn on the back of the stove, break into small pieces, and feed on the cob early enough so that the hens have a chance to pick off all they want before they go to bed.

The egg.[7]—In several respects an egg is similar to a grain, such as a kernel of corn. In each there is a germ, from which the new life develops, and each contains food for the nourishment of this germ. In the grain the stored food material is starch, fat, and protein, while in the egg the nutriment is stored in the form of protein and fat. While the grain must absorb much water for germination, the egg contains sufficient for its own development. Moreover, a much higher temperature is required for the hatching of the egg than for the germination of a seed.

An egg consists of five parts: (1) the shell; (2) the shell membrane; (3) the albumin; (4) the yolk; and (5) the germ. The *shell*, consisting of 3 layers, makes up from 10 to 11 per ct. of the weight of the entire egg. It is composed chiefly of calcium carbonate (carbonate of lime). The *shell membrane* consists of two layers, the inner one being the thinner. At the large end of the egg these layers separate, forming the air sac. The *albumin*, or the white of the egg, which forms about 59 per ct. of the weight, contains about 14 per ct. dry matter, this being nearly all protein. When an egg is cooked, this albumin coagulates or hardens. *The yolk*, forming about one-third of the egg, is enclosed in a delicate membrane which keeps it spherical in shape. The yolk contains about 49 per ct. water, 18 per ct. protein, 32 per ct. fat, and 1.5 per ct. ash. The *germ* in the fresh-laid egg is a white speck about one-eighth of an inch in diameter on one side of the yolk.

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[7] Largely adapted from Lippincott, Poultry Production, 1916.

The eggs of the different breeds of chickens vary somewhat in size, the average hen's egg being 2.27 inches long and 1.72 inches in diameter, and weighing about 2 ounces. This brings the weight of a dozen eggs to 1.5 lbs. Eggs from pullets are generally smaller than those laid by mature hens.

Selecting the flock.[8]—Under any method of feeding and care, success with poultry is possible only when good stock is kept. Since pure-bred fowls or eggs from such fowls for hatching can be obtained at reasonable prices, the wise poultryman will start with good stock and, if possible, keep improving it. To obtain the best chicks, eggs should be saved from strong, vigorous, reasonably mature stock. Only the best of each year's crop of pullets, those which mature early and are persistent layers, should be selected for breeding purposes. Such stock should be mated with vigorous males from a high-producing strain.

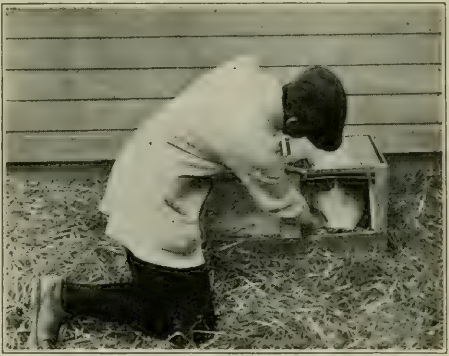

FIG. 110.—A HEN IN A TRAP NEST

By using trap nests the poultryman can find out how many eggs each hen actually produces. (From Halpin, Wisconsin Station.)

It will pay everyone who raises poultry to spend a little time during the fall and winter in marking the laying hens and pullets, leg bands being commonly used for this purpose. Good layers are first off the roost in the morning and the last to go to roost at night, are always busy looking for feed, and have full crops at night. They are bright-eyed, go about singing, and have full-sized red combs that are pliable and inclined to be slippery. Late moulting hens are really the best layers, but are discarded by many farmers, who have a mistaken belief that early moulting hens are the winter layers. Tho the close observer can usually distinguish between hens which are layers and those which are drones, the breeder who wishes to build up a high-producing flock should install trap nests and find out not only which hens are laying but also how many eggs each lays.

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[8] This and the following paragraphs on incubation and raising and feeding chicks are largely adapted from Halpin, Wis. Bul. 261.

Halpin points out: "Instead of breeding from the best hens, poultrymen often breed from the poorest. In many farm flocks there are hens that do not lay an egg during the fall or winter. In the spring these hens get out-of-doors and begin to lay. They are not used to the nests in the house and often hide their nests under a brush pile or in some other hiding place where they are not discovered. A hen of this type frequently lays but fifteen or twenty eggs a year. By 'stealing' her nest she manages to furnish half of the chicks that are raised. This is equal to saving heifer calves from the poorest cows in the herd."

Saving eggs for hatching.—To produce good eggs for hatching, the flock should be liberally fed and encouraged to take plenty of exercise, but should not be forced by a stimulating ration. When an incubator is used, eggs are commonly kept until enough have accumulated to fill the machine. Eggs should be kept only as long as is necessary, for the fresher the egg, the quicker the hatch, and the larger the chick produced. When held in a cool room at a temperature of about 50 degrees, eggs can be kept from 10 to 14 days without serious injury. It is best to keep the eggs on an egg tray or padded table top and to turn all of them each day.

A sufficient number of vigorous males should be placed with the females to ensure fertile eggs. With good strong males, from 10 to 15 hens of the general purpose breeds and 20 to 30 of the egg breeds may be mated to each male. When the fowls are confined to a small yard, less can be mated than when they have free range.

When enough eggs have been secured for hatching, the males should be kept separate from the flock, for males are not required for the maximum production of eggs and one of the largest losses in market eggs in spring and summer is caused by the development of the germ in fertile eggs. With infertile eggs this cannot occur.

Incubation.—Many people hatch the chicks too late in the season. They then seldom reach maturity before cold weather, and hence the pullets produce few if any winter eggs. This also results in stunting the pullets, for it is difficult to grow them well in winter in an ordinary house, and in the spring they have not reached normal size when they begin to lay. If hens are used for hatching, they should be well cared for during the winter so they will want to sit early in the spring. The smaller breeds have so little tendency to sit that usually an incubator must be used to secure early chicks.

Incubators are easy to operate, if the directions furnished with the machine are carefully followed. It is important to have the machine well regulated before putting in the eggs, to use good oil, and to keep the lamp and flues clean and the wick carefully trimmed so as to give a rounded flame. At hatching time the machine should be kept darkened so the chicks will sleep. The chicks are better if kept confined to the egg tray until dry or partially dry and then removed to the brooder, rather than letting them drop down into the nursery of the incubator. About 19 days are required for the incubation of eggs of the light breeds and 21 for those of the meat breeds.

Hatching eggs with hens.—When the eggs are hatched with hens, clean, roomy nests at least 14 inches square should be prepared in some building where the hens will not be disturbed while sitting. The nest should be placed over a layer of 3 or 4 inches of soil or sod and then littered with soft straw, hay, or shavings, the corners being well packed with litter. After placing 2 or 3 nest eggs in each nest, the hens are moved to the nest just at dark. The next day they should be taken off and given feed and water. If they do not return to the nests in 20 to 30 minutes they must be driven back or caught and fastened in the nest. As soon as the hens settle down they should be given the eggs. Until the eggs start to hatch, the hens should be taken off or allowed to come off each day. They should be fed all the whole corn they will eat, with an occasional allowance of mixed grain. Fresh water should be supplied daily and in hot weather it is wise to place a cup of water in each nest, as this saves much bowel trouble, which frequently spoils many hatchings. The hens should be allowed to wallow in a dirt bath and should be kept free from lice and mites by dusting with a good insect powder as soon as they become accustomed to the nest and at the end of the first and second weeks. In case mites are discovered move the hen and eggs to a new nest and disinfect the infested nest. Where possible, several hens should be set at one time. The infertile eggs should be removed toward the end of the first week, and, if there are many infertile ones, the fertile eggs can be given to a few of the hens and the rest be given fresh eggs.

Brooding chicks with hens.—In rearing chicks with hens, the essentials are few. The hen, quiet and motherly, should be placed in a light, portable coop which will allow the chicks free range but in which the hen can be confined if desired. The coop should protect the hen and the chicks from the weather and from enemies, and should be located on a grassy, shady range. Early in the season it is usually best to have board bottoms in the coop, but later in the season and in dry weather this is not necessary. When bottoms are used they should be kept clean and should be littered with chaff or fresh earth. When no bottoms are used the coop should be moved at least once every other day. This will prevent killing the grass and will fertilize a larger area.

As soon as the chicks are 10 days old, the mother hen may be turned loose toward night and allowed to run with the brood. If she does no damage, she can be given her liberty during the day when the chicks become accustomed to following her. On most farms the hens with their broods can be moved to some field where they can find a large part of their living. When the hens wean their chicks, care should be taken to see that the orphans do not desert some of the houses and all crowd together.

Many find it practicable to hatch most of their chicks in incubators and brood them all with hens. Others buy chicks from a central hatching station and rear them with hens. Broody hens are given a couple of chicks to test them out just at dark, and early the next morning the best mothers are selected and given from 12 to 30 chicks.

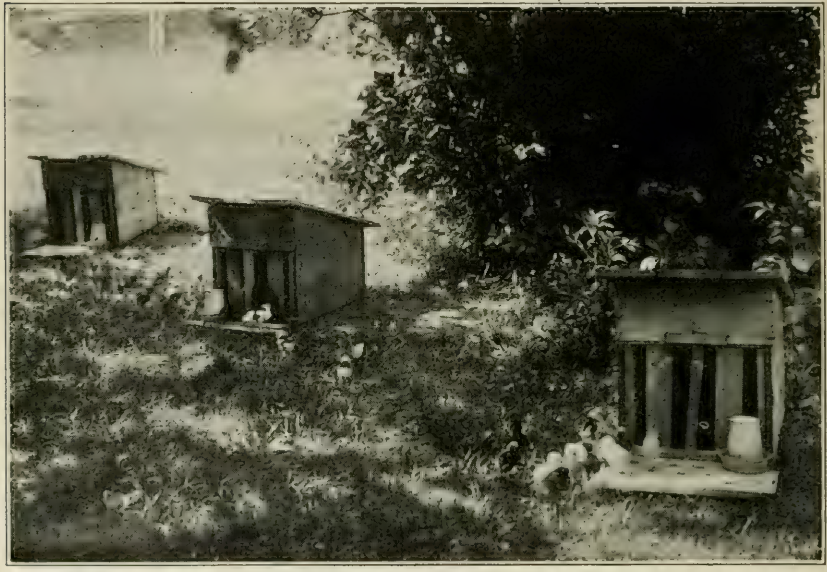

FIG. 111.—SUMMER HATCHED CHICKS NEED SHADE

Chicks have tender skins which are easily sunburned. Keep these inexpensive coops clean by moving them to a new spot every day. (From Halpin, Wisconsin Station.)

Artificial brooding.—While rearing chicks with hens is the proper method where only a few chicks are raised, the use of brooders is advisable where a large number must be cared for. Not only does this save labor but it permits raising the chicks past weaning entirely free from lice. Brooders are of two general types—indoor brooders and outdoor brooders. The former must be placed inside of some building for additional protection, while the latter may be used out-of-doors under ordinary climatic conditions. The essential parts consist of a heater (except in the case of fireless brooders for a few chicks), a warm-air compartment called the hover, a cool-air compartment, and a ventilating system. In operating a brooder, the most important points are cleanliness, steady and abundant heat under proper control, and opportunity for the chicks to get nearer the heat when they are cold and room to get away from it when they are too warm. Unless the heat is steady, the chicks may either be overheated or chilled at night before they awake and adjust their position nearer or farther away from the source of heat.

The brooder should be started at least 24 hours before it is needed for the chicks, and the temperature carefully regulated. After the chicks are transferred to the brooder, most persons will have better results if they do not depend on the thermometer in regulating the heat, but watch the chicks instead. Give enough heat so that they do not crowd to the warm part of the hover but spread out in the cooler part with their heads sticking out from under the curtain at night, or so that a chick that walks to the hottest part of the brooder stays there only a short time. To prepare the chicks for removal to the range, they must be hardened off gradually by reducing the temperature of the brooder after the second week. Heat is needed for about 6 weeks in the early spring in the northern states and for only 3 to 4 weeks later in the season. When heat is finally dispensed with a ''cold frame'' may be substituted for the hover. This is simply a box with a slitted curtain of soft, warm cloth on one side and a cover of similar cloth which is so loose that it sags down in the center and rests on the chicks' backs when they go into the frame to sleep or get warm.

Feeding the chicks.—Just before hatching, the yolk of the egg, which has hitherto not been used for food by the chick, is drawn into the body and supplies it with food for several hours after hatching. Due to this, it is advisable not to give chicks any solid food for some time after they are hatched—with incubator chicks at least 48 hours. After the first few days, the chicks must be fed liberally for they grow with great rapidity. Several methods may be followed with equal success in feeding chicks. The following, given by Halpin, will be suggestive:

First method.—Give the chicks sour milk in a small dish when they are 24 hours old. Keep this before them until they are about 72 hours old, when they are given good, sweet chick feed in a litter of chopped clover or alfalfa. This chick feed may be a mixture of finely cracked corn, cracked wheat, steel-cut oatmeal, and kafir, or such a mixture as 2 parts of finely cracked corn, 2 parts of cracked wheat, and 1 part of steel-cut oats. The chick feed is scattered over the litter at least 5 times a day, pains being taken to have the chicks out from under the hover to see the feed when it falls. The next day and thereafter they are given a very light feed of moist mash made up of equal parts of corn meal, rolled oats, bran, and middlings. This is moistened with sour milk. Any mash that is not eaten after 15 or 20 minutes is removed. This method of feeding is continued until the chicks are 3 weeks old, when the rolled oats are gradually dropped from the ration. At about this time whole wheat and medium cracked corn are added to the chick feed and are increased as rapidly as the chicks learn to eat it. As soon as they show a willingness to eat the coarser feed the fine feed is omitted. When the chicks are 2 weeks old, a small hopper is filled with a mash of 2 parts ground corn, 2 of bran and 1 of middlings. Another hopper containing meat scrap of a good grade is also placed in the pen. The chicks are given free access to these feeds. Green feed, grit, charcoal, and water should always be before them.

Second method.—Stale bread crumbs moistened with sour milk are fed after the chicks are 48 hours old. Squeeze bread nearly dry. Give sour milk or water to drink. After the first 5 days give a moist mash of bran and ground corn with chopped onions or other green feed. Feed wheat screenings and cracked corn after the first week. Early in the season stir this into a litter of clover chaff.

Third method.—Feed Johnny cake for the first 10 days. This is made as follows: Mix 1 pint of finely ground corn, 1 teacupful wheat bran, 1 teaspoonful ground meat, 1 teaspoonful soda, and 1 teacupful sour milk, and bake 1 hour. Feed 4 times a day. Stir a little chick feed or other fine grain into the litter. Provide green feed, grit, water, and charcoal.

Fourth method.—Feed chick feed in litter 5 times a day for the first 10 days; after that feed chick feed 3 times a day. Give in addition a moist mash made of equal parts of bran, ground corn, and ground barley (with coarse hulls sifted out) twice daily. Give milk, green feed, grit, water, and charcoal as recommended in first method.

When the chicks have ample range, they can often pick up in the form of worms and insects practically all of the animal feed that is necessary. However, where chicks are raised on a large scale, it always pays to supply additional animal matter. For this purpose, skim milk and buttermilk are the best, if they can be obtained. Other forms of animal feed are discussed in the following chapter. Ground bone, which should be fed in a hopper, supplies mineral elements that help the chick to grow a good, strong frame. Fresh, finely ground green bone can also be supplied, but care should be taken to see that it is fresh and sweet, and is fed in small quantities.

From the start the chick should have access to finely crushed rock, coarse sand, fine gravel, or specially prepared commercial grit. The "chick size" white limestone is especially valuable. Fine charcoal should also be supplied whenever possible. Both the grit and the charcoal may be mixed with the scratch feed and fed in small quantities, or each may be put into a separate compartment of a hopper after the first few days.

Pullets and cockerels.—Pullets should be grown in a movable colony house on the open range wherever possible. When given free range they may be allowed to help themselves to grain and mash in self-feeding hoppers. The grain feed may consist of equal parts of wheat and cracked corn, and the mash of equal parts of wheat bran, wheat middlings, and corn meal. If insects are not abundant meat scrap or milk should be given. Green feed should be supplied in case of drought. Water, grit, charcoal, and oyster shell should be accessible at all times.

The care of cockerels for the breeding flock does not differ from that for pullets. Those not to be kept for breeding may be sold while still on the range or may be fattened in crates. Successful crate fattening demands young and vigorous stock kept closely confined in clean crates or coops. The usual concentrate mixture consists of about 60 lbs. corn meal and 40 lbs. red dog flour or flour wheat middlings. Oat flour or barley flour are sometimes added. This feed is mixed with buttermilk at the rate of 1 quart of buttermilk to 1 lb. of dry feed. The fowls are given just a trifle less feed than they will clean up. Feeding is carried on for about 14 days and gains of about 35 per ct. in live weight are common.

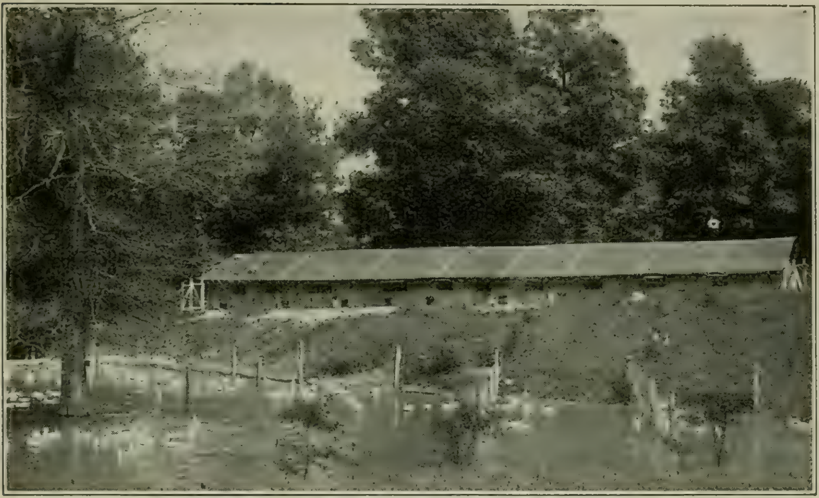

FIG. 112.—A PROFITABLE DUCK RANCH

Several poultrymen have made a pronounced success of raising ducks on a large scale. (From Wisconsin Station.)

Ducks.—The most profitable ducks are marketed at about 10 weeks of age when they weigh from 5 to 6 lbs. each. Young ducks should always be fed on ground feed, animal feed, green feed, and grit mixed into a crumbly mash. They may be started on 4 parts wheat bran, 1 part wheat middlings, and 1 part corn meal, with 5 per ct. grit added. From 4 to 6 days of age up to 4 or 5 weeks of age add 5 per ct. of meat scrap and plenty of green feed. From this time up to six weeks reduce the proportion of wheat bran to 3 parts. Then feed equal parts of wheat bran and corn meal, with 10 per ct. of meat scrap, 15 per ct. of middlings, and 10 per ct. of green feed. After 8 weeks of age, corn meal should form half the ration. The balance may be equal parts bran and middlings with 10 per ct. of the entire ration consisting of meat scrap, 3 per ct. of grit, and about 5 per ct. of green feed. At ten weeks they should be ready for market.

Old ducks during the laying season may be fed an ordinary poultry mash, with plenty of green feed and with 10 per ct. of the ration consisting of meat scrap. When not laying give good pasture and not over 5 per ct. of meat scrap in their mash.

Geese.—Breeding geese should have good pasture during the summer and clover hay, oats, and bran in winter. Young goslings are best started on bread and milk with plenty of green feed. After 2 weeks feed a light feed twice a day of equal parts wheat bran and corn meal moistened with milk. Always supply plenty of green stuff. When pasture is abundant they will need no other feed after 3 or 4 weeks of age.

Turkeys.—Young turkeys should be fed sparingly a mixture of finely chopped hard boiled eggs, green stuff, and rolled oats. Feed only what the poults will eat in about five minutes. Fine, sweet chick feed follows in a few days. Feed sparingly and allow the poults to "pick" as much of their living as possible on the range. Overfeeding kills many each year. Breeding turkeys should be fed a mixture of grains and occasionally be given some green feed during the winter.

Hints on feeding poultry.—For good production, either of meat or of eggs, animals must consume a large amount of feed. Hence, feeds must be provided which are palatable and attractive. The art of feeding lies in stimulating the appetite of the flock so that the birds will eat heartily; yet over feeding must be avoided, for this causes loss of appetite and makes the birds lazy. The skilled feeder seeks to feed growing, laying, or fattening poultry just a little less than they would like to eat. It might appear that feeding young stock on the range grain in hoppers or allowing laying hens to eat dry mash in hoppers at all times is contrary to this rule. However, as Lippincott points out,[9] in both these cases the amount of the most palatable kind of feed is limited. On range the chicks are so eager to secure bugs and worms that they do not overeat of the hopper-fed grain. The laying hens prefer the scratching grain fed in the litter to the finely ground dry mash fed in the hopper, and usually eat only enough of the latter to piece out the allowance of scratching feed.

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[9] Lippincott, Poultry Production, 1916, p. 366.

Feeding and watering should always be done at regular times for all classes of poultry. At the customary feeding hour the birds will congregate at the place of feeding, waiting for the appearance of the feeder. If feeding time is long delayed, they become irritated and tend to eat less, which cuts down production.

Supplying a considerable variety of feeds stimulates the appetite and encourages the consumption of a large amount of feed. At least two grains should preferably be given in the scratch feed and three different feeds in the mash, in addition to green feed, and such animal feed as meat scrap or milk. All feeds should be sound and wholesome, as stale, moldy feeds often cause loss of appetite, diarrhea, and other digestive disorders. Also, feeds should always be given in clean litter, troughs, and hoppers.

QUESTIONS

1. How does the hen compare in efficiency of food production with other live stock?
2. Tell how the digestive system of poultry differs from that of other farm animals.
3. Discuss the nutrient requirements of poultry.
4. What forms of mineral matter are fed to poultry and why?
5. Discuss the requirements of poultry for animal food, salt, water, and charcoal.
6. Describe the kind of poultry house you would build.
7. Why is mash commonly fed to poultry?
8. What is the value of green feed for poultry?
9. Describe the various types of fowls.
10. Tell how you would feed laying hens.
11. Give an example of a good laying ration.
12. Describe the structure of the egg.
13. What points are of special importance in selecting the flock?
14. Discuss (a) saving eggs for hatching; (b) incubation; (c) hatching eggs with hens; (d) brooding chicks with hens; and (e) artificial brooding.
15. How would you feed (a) chicks; (b) pullets; (c) fattening cockerels?
16. Tell about the feeding (a) of young ducks; (b) laying ducks; (c) geese; (d) turkeys.

CHAPTER XXX

FEEDS FOR POULTRY

I. Carbonaceous Concentrates

Because of the nature of their digestive tract, poultry can utilize but little roughage, so important a part of the rations for horses, cattle, and sheep. Indeed, poultry make even less use of feeds high in fiber than do swine. The common cereals and their by-products are usually bulky enough for poultry, and roughages have small place in their rations, except when fed green for succulence. Since the cereals are all rather low in protein, they should be supplemented by protein-rich feeds, such as meat scrap, skim milk or buttermilk, wheat bran, linseed meal, etc.

Indian corn.—Corn is the chief grain fed to poultry in most parts of this country, principally because they prefer it to all other cereals, because it is rich in starch and fat, and because it is commonly the cheapest source of digestible nutrients among the grains, from the corn belt eastward. Since it is low in protein and mineral matter and is also very concentrated, corn should not be fed alone, but should be supplemented by bulkier feeds and those rich in the nutrients it lacks. The low egg production of many farm flocks is undoubtedly often due to the exclusive feeding of corn. Properly combined with feeds rich in protein and mineral matter, especially calcium and phosphorus, and fed with some bulky feed, such as green food or cut clover, corn gives excellent results. Yellow corn produces darker colored yolks and yellower body fat than white corn or the other cereals.

Cracking or grinding corn does not increase its digestibility for poultry, but many crack it to force the birds to take more exercise in picking up a full meal. Except for chicks, the grain is coarsely cracked. Corn meal is the foundation of most poultry mashes.

Wheat; wheat screenings.—*Wheat*, commonly considered the best single grain for poultry, is preferred by them to all other grain except corn. Because of its high cost, it is not usually economical to feed wheat as the chief grain, but a limited amount is an excellent addition to the ration. Tho carrying more protein than corn, it should be supplemented by protein-rich feeds. Soft wheat is more palatable to poultry than that having hard kernels. Shrunken wheat, which is unfit for flour making and is hence cheaper, is richer in protein and fully as valuable for feeding as plump wheat.

Wheat screenings, when of good quality and not musty or smutted, are satisfactory for poultry. The value depends on the proportion of shrunken wheat and weed seeds to worthless trash.

Oats.—Due to the large amount of fiber in the hulls, oats rank below corn or wheat for supplying nutrients. They are also usually costly compared with corn and are not well relished by poultry. However, mixed with other concentrates, they are useful in giving bulk to the ration and adding variety. Plump, heavy oats should be used for poultry as the hulls are almost worthless for them. Whole oats or clipped oats are often fed as part of the scratch feed, rolled oats and pin-head oat meal are favorite feeds for baby chicks, and hulled oats are esteemed for older chicks. As pointed out later in this chapter, sprouted oats are an excellent succulent feed.

FIG. 113.—POULTRY RAISING FITS INTO INTENSIVE AGRICULTURE

The truck gardener or the fruitgrower can often increase his profits by raising poultry. The illustration shows chickens ranging on land planted to corn and young fruit trees. (From Indiana Station.)

Barley.—Tho less palatable than corn or wheat, barley is an excellent grain for poultry, being nearly equal to these grains in feeding value. In sections of the West it is the most common grain for poultry.

The sorghums; millet.—*Kafir* is well liked by poultry and is nearly equal in value to corn or wheat. It is used in many proprietary poultry feeds. *Milo* should be equal or slightly superior to kafir. Seed from *sweet sorghum* and *broom corn* is also satisfactory for poultry. *Millet* seed is often used as a feed for young chicks. However, as it is higher in fiber than wheat or corn, it is less valuable than these grains. It may be injurious when fed in large amounts.

Other carbonaceous feeds.—*Rye* is fed but little to poultry in America, as the other cereals are much more palatable.

Rice is not commonly fed to poultry except when off grade. Broken rice, resulting from the manufacture of table rice, is used in some commercial chick feeds.

Buckwheat is usually relished by poultry and forms a welcome addition to the scratch feed. It is usually too high in price to feed except in districts where it is grown.

Emmer is well liked by poultry and resembles oats in feeding value.

Sometimes *salvage grain* may be secured at a price which makes its use economical.

Hominy feed, tho little used for poultry, is worth fully as much as corn meal.

Dry, stale *bread,* which can often be secured cheaply from bakeries, gives good results as part of the mash. Dried bread crumbs or cracker crumbs soaked in milk are often fed to young chicks.

II. PROTEIN-RICH CONCENTRATES

Meat scrap.—As has been pointed out in the preceding chapter, feeds of animal origin are of especial importance for poultry. In summer poultry having abundant range can gather a considerable amount of animal feed in the form of insects and worms, thus reducing the amount that need be supplied. Of animal feeds, the most widely used is meat scrap, tho in dairy districts it is wisely being replaced by skim milk and buttermilk. In purchasing meat scrap, special attention should be paid to the guaranteed amount of protein, for the high-grade brands, carrying 55 to 60 per ct. of protein or over, are usually much more economical than the lower grades, which usually cost but a few dollars per ton less. Meat scrap should form from 5 to 25 per ct. of the dry mash, depending on the amount of protein supplied in the other ingredients of the mash and in the scratching grain. Of course, less need be supplied poultry which have ample range in summer. Poultry do not relish dried blood or tankage.

Fresh meat.—When fresh meat or meat scraps can be secured cheaply, they are even more satisfactory than dried meat scrap, on account of their greater palatability. It should be remembered that fresh lean meat contains but about 40 per ct. as much protein as high-grade dried meat scrap, and consequently more must be used to balance the ration.

Skim milk; buttermilk; whey.—These dairy by-products are fully as satisfactory protein-rich feeds as dried meat scrap. They may be given as a drink or may be used to mix with the mash, the latter being a common practice in the commercial fattening of poultry. Skim milk or buttermilk is especially valuable for young chicks. Sour skim milk is preferred to sweet for poultry.

Whey, tho of much less value than skim milk or buttermilk, may be used with good results as a drink or for moistening mashes. In using whey, it should be remembered that it is only fairly rich in protein.

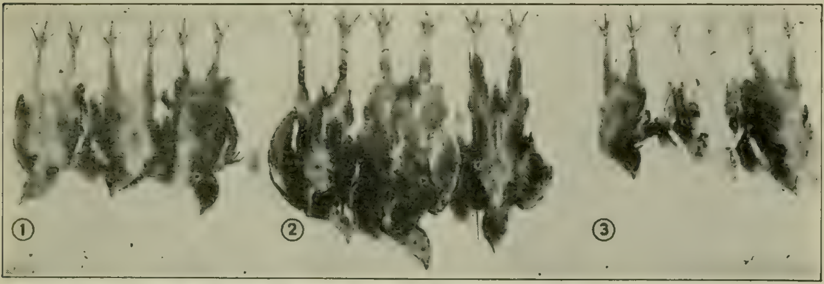

Fig. 114.—Milk Is an Ideal Feed for Growing Chicks

(1) Chicks, 6 weeks old, fed wheat and green clover; (2) chicks, same age, fed cracked corn, green clover, and milk; (3) chicks, same age, fed cracked corn and green clover. The chicks fed milk gained about 4 times as much as Lot I or Lot III. None of them died, while the death rate in Lot I was 16 per ct. and in Lot III 40 per ct. (From Halpin, Wisconsin Station.)

Fish scrap; fresh fish.—A good grade of fish scrap, from which most of the oil has been expressed, is a satisfactory substitute for meat scrap. The kind of fish scrap usually sold for fertilizer should not be employed. Fresh fish are frequently fed in winter but care should be taken to see that all tainted or spoiled meat is rejected, lest the fowls be made sick or bad-flavored eggs result.

Milk albumin.—This is a trade name for a by-product obtained in the manufacture of milk sugar from skim milk. In the process the casein is precipitated by lime and the resulting cake, composed of casein and lime, is ground and sold as milk albumin. It is a good source of protein and is palatable to poultry, but is usually high in price.

Green cut bone.—Many poultrymen secure from meat shops fresh bones with adhering meat, grind them in bone cutters, and feed while still fresh. Green cut bone of good quality is a highly satisfactory animal feed, but its use is limited, as it will keep but a short time, and it is often difficult to secure a supply regularly. When necessary to hold fresh ground bone even for a comparatively few hours it should be spread out thinly. A paper sack full of fresh ground green bone will frequently spoil over night, even in a cold room. If spread out thinly it can be kept in a warmer room, where there is no danger of freezing.

Wheat by-products.—*Wheat bran* forms part of most mashes for poultry, adding bulk to a mixture of heavier concentrates. Even when bran is high in price, compared with other feeds, the use of a limited amount may be advisable on account of its slightly laxative and cooling effect. *Middlings* are used in most poultry mashes.

Linseed meal.—Because of its beneficial effect on the digestive system and its laxative action, linseed meal is a valuable feed for poultry, but should not form over 10 per ct. of the ration. It is undesirable for use in wet mashes because of its gummy nature and is unpalatable when fed in large amounts. Old-process linseed meal is especially helpful during the moulting season and in fitting birds for shows, as it hastens the growth of feathers and gives them luster.

Cottonseed meal.—Contradictory results have been secured in trials where cottonseed meal has been fed to poultry. In some cases it has been substituted successfully for dried meat scrap, but in others the results have been much less satisfactory. As a result, poultrymen at present do not favor this concentrate.

Sunflower seeds.—Sunflower seeds, rich in oil and high in protein, are often used in fitting poultry for shows and as a conditioner during the moulting season, since they hasten the growth of feathers and give luster, the same as does linseed meal. They are frequently grown for shade in poultry yards, the heads being fed to the flock. Except when thus used they are rarely economical for general use in balancing the ration.

Miscellaneous protein-rich concentrates.—*Wet brewers' grains* are excellent for poultry, if fed fresh, for they are palatable and succulent.

Dried brewers' grains are often economical to use as part of the mash. *Gluten feed*, palatable and satisfactory for poultry, is commonly an economical protein-rich feed, due to its richness in protein and its high digestibility.

Buckwheat middlings and *buckwheat bran* of good grade may be used as a substitute for wheat bran in mashes. Low-grade bran, containing much hulls, should not be fed to poultry.

Field peas, *soybeans*, and *cowpeas* are all satisfactory for poultry, but are not commonly fed because they are usually high in price.

Meal from these protein-rich seeds may be used as part of the mash to balance the ration.

III. Succulent Feeds and Roughages

Mangels.—For winter feeding, mangels are one of the best succulent feeds, due to the ease of growth and large yield, and to the fact that they keep well during the winter. A good method of feeding is to split the beets lengthwise and stick the halves on nails driven in the walls of the pen, about 18 inches from the floor, and then allow the fowls to pick at them.

Cabbage.—Cabbage is highly relished by poultry and is probably the best green feed for fall and early winter use. Experiments at the Wisconsin Station[1] seem to give cabbage first place among the green feeds, especially while the hens are moulting. The cabbage should be fastened to a wire clamp on a string suspended from the ceiling, and should be about 18 inches above the floor, so that the birds may reach it easily.

Sprouted oats.—The sprouting of oats to furnish succulent feed during the winter is increasing in popularity among poultrymen. Tho oats may be sprouted in several ways, the following is the method usually employed: The oats are placed in a pail or tub, which is filled with water at a temperature of not over 100° F., to which are added 10 drops of formalin for each 10 quarts.[2] The oats are allowed to soak over night in a warm room and next morning they are spread to a depth of one inch on a tray. This is commonly placed in a rack, made to hold at least 7 trays. The oats are kept in a room in which the temperature is not lower than 60° F., and are sprinkled with warm water once or twice a day. In 7 to 10 days the top sprouts will be 2 to 3 inches long and the oats ready for use. They are usually fed in broad, flat troughs, no more being given than the birds will clean up within half an hour.

Other succulent feeds for winter.—Sugar beets are satisfactory for poultry but are usually more expensive per pound of dry matter contained than are mangels. *Turnips* and *rutabagas* may be fed to poultry but should be used in moderation or they will impart a bad flavor to the eggs. They are especially suited for fall feeding, as they do not keep as well as mangels.

Silage of good quality may be fed to poultry with good results, but nearly all poultrymen prefer some other form of succulence. In feeding corn silage care should be taken to choose the leafy part rather than that which is largely corn. Silage should be fed in small quantities until the flock becomes accustomed to it.

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[1] Halpin, Information to the authors.

[2] Lewis, Productive Poultry Husbandry, 1914, p. 189.

Green feeds for spring and summer.—For early spring *rye pasture* is an excellent green feed. To prevent scours the fowls should not be allowed to eat a large amount of the rye until they become accustomed to it. *Green alfalfa* and *green clover* furnish excellent grazing for poultry or may be cut as soilage and fed to birds confined to bare lots. *Rape,* planted early, may be pastured thruout the season, or will yield several cuttings, if not cut below the crown. *Lettuce* is excellent for broiler chicks in early spring before other green feed is available. *Onion tops* and *onions* are relished by poultry when fed in small amounts, and give variety to the ration. Too large amounts fed to laying hens will taint the eggs. Sliced *onions* are the best of all green feeds for very small chicks but are not usually fed in large quantities because of the high cost.

Legume hay.—The only dry roughage of any value for poultry is cut or ground legume hay. This is often used as part of the dry mash to increase its bulk, up to one-fourth of the mash consisting of the legume hay. *Alfalfa* hay is used somewhat more commonly than *clover* hay, tho there is little difference in their value. Poultry, however, prefer clover to alfalfa. Cut alfalfa or clover hay, when steamed, may be used as a temporary substitute for succulent feed. On the farm, the leaves which shatter from legume hay in feeding to other stock should be saved for the poultry. Alfalfa or clover meal is not better than the finely cut hay.

QUESTIONS

1. What precautions should be used in feeding corn to poultry?
2. What grain is commonly considered the best single grain for poultry? Discuss its use.
3. How do oats and barley compare with corn and wheat for poultry?
4. What is the value for poultry of the sorghums, millet, rye, rice, buckwheat, emmer, hominy feed, and stale bread?
5. Discuss the value of the most widely used animal feed.
6. Tell what you can about 6 other animal feeds used for poultry.
7. What is the use in poultry feeding of wheat bran, wheat middlings, linseed meal, cottonseed meal, and sunflower seeds?
8. Discuss the value of the 3 best succulent feeds for winter feeding.
9. What other succulent feeds are used in flocks in your vicinity in winter and in the growing season?
10. How is legume hay used in poultry feeding?

APPENDIX

TABLE I. AVERAGE COMPOSITION OF AMERICAN FEEDING STUFFS

The following averages, showing the composition of the most important American feeding stuffs, are taken from the much more extensive table in the unabridged edition of *Feeds and Feeding.* This table and Appendix Tables II and III are based upon an exhaustive compilation, made by the authors, of the analyses and digestion coefficients reported by the State Experiment Stations and the United States Department of Agriculture. The completeness and accuracy of the data here presented is evident from the fact that merely the preparation of the unabridged tables required the time of trained assistants equivalent to one person working steadily for three years, in addition to the supervision of the authors. The student desiring to know the composition and digestibility of feeding stuffs not given in these tables is referred to the exhaustive tables in the unabridged *Feeds and Feeding.*

This table and Appendix Tables II and III are fully protected by copyright.

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
CONCENTRATES	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Grains and seeds							
Barley	9.3	2.7	11.5	4.6	69.8	2.1	298
Broom-corn seed	11.8	2.9	10.2	8.2	63.5	3.4	4
Buckwheat	12.1	2.1	10.8	10.3	62.2	2.5	18
Corn, dent	10.5	1.5	10.1	2.0	70.9	5.0	440
Corn, flint	12.2	1.5	10.4	1.5	69.4	5.0	52
Corn, soft	30.6	1.0	7.4	1.2	56.0	3.8	154
Corn, sweet, mature	9.3	1.8	11.5	2.3	67.2	7.9	67
Corn-and-cob meal	10.4	1.5	8.5	7.9	67.6	4.1	....
Corn and oat feed	11.4	2.8	9.6	7.4	65.0	3.8	1,789
Corn and oat feed, low grade	9.5	4.6	8.9	13.7	59.7	3.6	386
Cotton seed	9.4	4.6	19.5	22.6	24.9	19.0	38
Cowpea	11.6	3.4	23.6	4.1	55.8	1.5	30
Durra grain	9.9	2.0	10.1	1.7	72.8	3.5	5
Emmer (spelt)	8.7	3.7	11.9	10.1	63.7	1.9	37
Feterita grain	10.8	1.5	11.5	1.2	71.7	3.3	1
Flax seed	9.2	4.3	22.6	7.1	23.2	33.7	50
Horse bean	12.6	3.8	26.2	7.1	49.4	0.9	2
Kafir grain	11.8	1.7	11.1	2.3	70.1	3.0	135
Kafir-head chops	12.5	2.8	9.7	6.4	65.9	2.7	21
Kaoliang grain	9.9	1.9	10.5	1.5	71.9	4.3	12
Hog, or broom-corn, millet seed	9.1	3.3	11.8	7.8	64.7	3.3	52
Milo grain	10.7	2.8	10.7	2.4	70.5	2.9	125
Milo-head chops	10.3	3.1	10.0	5.9	68.1	2.6	40
Oats	9.2	3.5	12.4	10.9	59.6	4.4	490

TABLE I. AVERAGE COMPOSITION OF AMERICAN FEEDING STUFFS—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
CONCENTRATES—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Grains and seeds—con.							
Peanut, with hull	6.5	4.1	20.4	16.4	16.4	36.2	2
Pea, field	9.2	3.4	22.9	5.6	57.8	1.1	6
Rice, rough	9.6	4.9	7.6	9.3	66.7	1.9	10
Rye	9.4	2.0	11.8	1.8	73.2	1.8	108
Shallu grain	9.7	1.6	12.5	1.7	71.1	3.4	3
Sorghum grain	12.7	1.9	9.2	2.0	70.8	3.4	13
Soybean	9.9	5.3	36.5	4.3	26.5	17.5	121
Velvet bean, seed	11.7	2.6	20.8	7.5	51.0	6.4	2
Velvet bean, seed and pod	12.3	4.0	17.1	14.3	47.7	4.6	1
Wheat, all analyses	10.2	1.9	12.4	2.2	71.2	2.1	858
Wheat, spring	10.1	2.0	12.5	2.7	70.5	2.2	109
Wheat, winter	10.9	1.8	11.7	2.0	71.6	2.0	94
By-products of factories, etc.							
Beet pulp, dried	8.2	3.5	8.9	18.9	59.6	0.9	48
Beet pulp, molasses-	7.6	5.6	9.5	15.9	60.7	0.7	21
Beet pulp, wet	90.7	0.4	0.9	2.1	5.7	0.2	10
Brewers' grains, dried	7.5	3.5	26.5	14.6	41.0	6.9	431
Brewers' grains, wet	75.9	1.0	5.7	3.6	12.1	1.7	47
Buckwheat bran, high grade	11.2	4.2	22.3	7.1	49.4	5.8	12
Buckwheat feed, good grade	11.8	4.4	19.3	17.9	41.4	5.2	18
Buckwheat feed, low grade	11.9	3.2	13.3	28.5	39.7	3.4	29
Buckwheat hulls	10.3	2.1	4.4	43.7	38.5	1.0	15
Buckwheat middlings	12.0	4.8	28.3	4.8	42.7	7.4	54
Cocoanut meal, low in fat	9.6	4.9	20.9	11.2	45.3	8.1	11
Corn bran	10.0	2.4	9.7	9.8	62.4	5.7	77
Corn cob	10.0	1.5	2.0	31.8	54.3	0.4	46
Cold-pressed cottonseed cake	7.9	4.2	26.1	24.0	30.1	7.7	64
Cottonseed meal, choice	7.5	6.2	44.1	8.1	25.0	9.1	2,556
Cottonseed meal, prime	7.8	6.6	39.8	10.1	27.4	8.3	1,322
Cottonseed meal, good	7.9	6.4	37.6	11.5	28.4	8.2	482
Cottonseed feed	8.3	4.9	24.5	21.4	34.6	6.3	406
Cottonseed hulls	9.7	2.7	4.6	43.8	37.3	1.9	66
Distillers' grains, dried, from corn	6.6	2.6	30.7	11.6	36.3	12.2	114
Distillers' grains, dried, from rye	7.2	3.9	23.1	10.9	47.1	7.8	7
Distillers' grains, wet	77.4	0.6	4.5	2.8	13.1	1.6	3
Flax feed	9.4	7.3	16.6	11.2	41.3	14.2	9
Flax screenings	8.6	8.2	15.4	15.5	40.5	11.8	13
Germ oil meal	8.9	2.7	22.6	9.0	46.0	10.8	36
Gluten feed	8.7	2.1	25.4	7.1	52.9	3.8	800
Gluten meal	9.1	1.1	35.5	2.1	47.5	4.7	307
Hominy feed	10.1	2.6	10.6	4.4	64.3	8.0	778
Linseed meal, new process	9.6	5.6	36.9	8.7	36.3	2.9	182
Linseed meal, old process	9.1	5.4	33.9	8.4	35.7	7.5	714
Malt sprouts	7.6	6.1	26.4	12.6	45.6	1.5	253
Molasses, beet	25.3	5.2	3.5	...	66.0	...	5
Molasses, cane, or blackstrap	25.8	6.4	3.1	...	64.7	...	16

TABLE I. AVERAGE COMPOSITION OF AMERICAN FEEDING STUFFS—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
CONCENTRATES—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct	
By-products of factories, etc.—con.							
Oat bran	6.4	6.1	12.2	18.3	52.3	4.7	5
Oat dust	6.6	7.0	12.6	18.7	49.9	5.2	5
Oat feed, low grade	10.2	4.0	9.6	18.5	53.8	3.9	8
Oat hulls	6.8	6.0	4.0	29.2	52.3	1.7	16
Oat middlings	7.3	3.2	16.3	4.6	61.8	6.8	23
Peanut cake, from hulled nuts	10.7	4.9	47.6	5.1	23.7	8.0	2,480
Potato flakes, dried	12.1	4.0	7.1	2.9	73.6	0.3	....
Red dog flour	11.1	2.5	16.8	2.2	63.3	4.1	259
Rice bran, high grade	10.1	9.7	12.1	12.4	44.3	11.4	831
Rice bran, low grade	9.5	11.3	10.9	15.8	42.7	9.8	475
Rice hulls	9.3	16.9	3.3	35.4	34.0	1.1	15
Rice polish	10.0	4.8	11.9	1.9	62.3	9.1	1,013
Rye bran	11.4	3.5	15.3	4.0	62.7	3.1	26
Rye feed (middlings and bran)	11.5	3.8	15.3	4.7	61.5	3.2	186
Rye middlings	11.4	3.7	15.7	4.6	61.2	3.4	128
Soybean meal, fat extracted	11.8	5.4	41.4	5.3	28.7	7.4	6
Wheat bran	10.1	6.3	16.0	9.5	53.7	4.4	7,742
Wheat feed (middlings and bran)	10.1	5.2	16.8	7.6	55.7	4.6	1,601
Wheat flour, patent	12.3	0.5	10.9	0.4	74.6	1.3	73
Wheat middlings, flour	10.7	3.7	17.8	4.7	58.1	5.0	470
Wheat middlings, standard (shorts)	10.5	4.4	17.4	6.0	56.8	4.9	4,641
Wheat screenings	10.2	3.9	13.3	7.4	61.1	4.1	66
Animal products							
Buttermilk	90.6	0.7	3.6	...	5.0	0.1	....
Cow's milk, whole	86.4	0.7	3.5	...	5.0	4.4	1,647
Dried blood	9.7	3.3	82.3	...	3.8	0.9	45
Fish meal, high in fat	10.8	29.2	48.4	...	...	11.6	6
Meat-and-bone meal, 30–40% ash	6.0	36.8	39.8	2.1	4.1	11.2	59
Meat scrap, high grade	7.5	16.6	59.3	...	5.0	11.6	....
Meat scrap, fair grade	6.7	25.5	52.0	...	5.4	10.4	....
Poultry bone	7.3	61.7	24.3	...	3.6	3.1	24
Skim milk, centrifugal	90.1	0.7	3.8	...	5.2	0.2	....
Tankage, over 60% protein	7.4	10.5	63.1	3.6	2.5	12.9	42
Tankage, 55–60% protein	7.5	13.6	58.1	4.9	2.9	13.0	57
Tankage, 45–55% protein	7.5	19.7	51.7	3.0	4.2	14.0	53
Whey	93.4	0.7	0.8	...	4.8	0.3	...
DRIED ROUGHAGE							
Hay and cured forage from grasses and cereals							
Barley hay, common	7.4	6.4	7.0	29.7	47.3	2.2	5
Bermuda hay	9.7	7.6	7.1	25.6	48.2	1.8	14
Bluegrass hay, Kentucky	13.2	6.6	8.3	28.3	40.7	2.9	26
Brome hay	8.5	7.7	9.9	31.3	40.2	2.4	8
Crab grass hay	9.5	8.5	8.0	28.7	42.9	2.4	9
Corn fodder (ears, if any, remaining), very dry, from barn or arid districts	9.0	6.5	7.8	27.2	47.3	2.2	56

TABLE I. AVERAGE COMPOSITION OF AMERICAN FEEDING STUFFS—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
DRIED ROUGHAGE—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Hay and cured forage from grasses and cereals—con.							
Corn fodder, medium in water ...	18.3	5.0	6.7	22.0	45.8	2.2	59
Corn fodder, high in water	39.3	3.6	4.8	16.7	34.2	1.4	23
Corn fodder, sweet	12.3	9.0	9.2	26.4	41.3	1.8	6
Corn stover (ears removed), very dry	9.4	5.8	5.9	30.7	46.6	1.6	183
Corn stover, medium in water ...	19.0	5.5	5.7	27.7	40.9	1.2	97
Corn stover, high in water	41.0	3.8	3.9	20.1	30.2	1.0	247
Fowl meadow grass hay	11.1	7.2	9.8	28.8	40.4	2.7	5
Foxtail or wild barley hay	7.5	8.8	7.0	27.4	47.3	2.0	5
Japanese cane fodder	6.8	2.0	1.4	20.6	67.3	1.9	1
Johnson grass hay	10.1	7.5	6.6	30.2	43.5	2.1	17
Kafir fodder, dry	9.0	9.4	8.9	26.8	43.1	2.8	20
Kafir fodder, high in water	28.3	3.3	6.5	21.6	37.6	2.7	2
Kafir stover, dry	16.3	8.3	5.1	27.4	41.2	1.7	3
Millet hay, barnyard	13.5	8.2	8.3	27.6	40.8	1.6	14
Millet hay, common, or Hungarian	14.3	6.3	8.3	24.0	44.3	2.8	56
Millet hay, German	8.7	6.9	8.0	27.3	46.5	2.6	22
Milo fodder, dry	11.1	9.9	12.0	18.4	44.1	4.5	5
Natal grass hay	9.8	5.0	7.4	36.8	39.2	1.8	....
Oat hay	12.0	6.8	8.4	28.3	41.7	2.8	72
Orchard grass hay	11.6	6.9	7.9	30.3	40.4	2.9	46
Para grass hay	9.8	6.6	4.6	33.6	44.5	0.9	3
Prairie hay, western	6.5	7.7	8.0	30.5	44.7	2.6	42
Red top hay	9.8	6.8	7.4	28.7	45.0	2.3	40
Sorghum fodder, dry	9.7	7.8	7.4	26.1	45.9	3.1	22
Sorghum fodder, high in water ..	37.4	3.1	3.9	17.8	35.0	2.8	11
Sudan hay	10.0	6.4	6.1	30.6	45.4	1.5	4
Teosinte hay	10.6	10.3	9.1	26.4	41.7	1.9	4
Timothy hay, all analyses	11.6	4.9	6.2	29.9	45.0	2.5	221
Timothy hay, cut before bloom ...	7.2	6.6	9.8	28.1	45.1	3.2	7
Timothy hay, cut at early to full bloom	12.8	4.6	6.3	29.5	44.2	2.6	50
Timothy hay, cut at late bloom ..	14.9	4.5	5.5	28.3	44.0	2.8	21
Timothy rowen hay	15.1	6.9	14.4	24.3	34.9	4.4	3
Wheat hay	8.1	6.4	6.2	24.7	52.6	2.0	12
Hay from the legumes							
Alfalfa, all analyses	8.6	8.6	14.9	28.3	37.3	2.3	250
Alfalfa, before bloom	6.2	10.0	22.0	20.5	37.1	4.2	11
Alfalfa, in bloom	7.5	10.0	15.0	30.2	35.5	1.8	31
Alfalfa, in seed	10.4	7.0	12.2	27.6	40.3	2.5	10
Alfalfa meal	8.8	9.0	14.3	30.1	35.8	2.0	176
Alfalfa leaves	6.6	13.6	22.5	12.7	41.2	3.4	6
Beggarweed	9.1	8.4	15.4	27.5	37.3	2.3	11
Clover, alsike	12.3	8.3	12.8	25.7	38.4	2.5	32
Clover, bur	7.0	10.8	19.2	23.0	37.0	3.0	11
Clover, crimson, or scarlet	10.6	8.8	14.1	27.3	36.9	2.3	18

TABLE I. AVERAGE COMPOSITION OF AMERICAN FEEDING STUFFS—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
DRIED ROUGHAGE—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Hay from the legumes—con.							
Clover, mammoth red	18.7	6.2	10.8	27.0	34.2	3.1	19
Clover, red, all analyses	12.9	7.1	12.8	25.5	38.7	3.1	76
Clover, red, in bloom	13.9	7.4	13.1	23.1	39.1	3.4	18
Clover, red, after bloom	22.1	6.0	11.6	21.9	33.8	4.6	5
Clover and mixed grasses	10.1	6.4	9.9	28.5	42.3	2.8	34
Clover and timothy	12.2	6.1	8.6	29.9	40.8	2.4	52
Clover, sweet, white	8.6	7.2	14.5	27.4	40.1	2.2	18
Clover, white	8.1	8.0	16.2	23.2	41.6	2.9	7
Clover rowen	14.8	7.3	16.5	20.4	37.3	3.7	2
Cowpea	9.7	11.9	19.3	22.5	34.0	2.6	35
Lespedeza, or Japan clover	11.8	5.8	12.1	25.9	41.6	2.8	14
Pea, field	11.1	7.9	15.1	24.5	37.9	3.5	30
Peas and oats	16.6	7.3	11.4	25.6	36.5	2.6	30
Peanut vine, with nuts	7.8	6.8	13.3	24.3	37.4	10.4	3
Peanut vine, without nuts	21.5	8.7	9.1	20.2	36.8	3.7	7
Soybean hay	8.6	8.6	16.0	24.9	39.1	2.8	23
Velvet bean	7.2	7.4	16.4	27.5	38.4	3.1	4
Vetch, common	7.1	8.2	17.3	26.2	38.7	2.5	3
Vetch, hairy	12.3	8.6	19.9	24.8	31.6	2.8	15
Vetch and oats	15.7	6.7	10.6	27.2	37.3	2.5	8
Vetch and wheat	15.0	6.8	14.5	27.2	34.4	2.1	4
Straw and chaff							
Barley straw	14.2	5.7	3.5	36.0	39.1	1.5	97
Bean straw	10.5	7.2	7.3	30.8	42.9	1.3	5
Buckwheat straw	9.9	5.5	5.2	43.0	35.1	1.3	3
Cowpea straw	8.5	5.4	6.8	44.5	33.6	1.2	1
Crimson clover straw	12.3	7.0	7.5	38.8	32.9	1.5	3
Flax shives	7.2	7.0	7.2	42.5	32.9	3.2	11
Millet straw	14.2	5.2	3.6	35.8	39.7	1.5	6
Oat chaff	8.2	11.5	5.9	25.7	46.3	2.4	4
Oat straw	11.5	5.4	3.6	36.3	40.8	2.4	41
Rice straw	7.5	14.5	3.9	33.5	39.2	1.4	13
Rye straw	7.1	3.2	3.0	38.9	46.6	1.2	7
Soybean straw	11.9	6.8	5.6	36.8	37.2	1.7	8
Wheat chaff	14.4	7.2	4.2	28.0	44.8	1.4	1
Wheat straw	8.4	5.2	3.1	37.4	44.4	1.5	27
FRESH GREEN ROUGHAGE							
Green forage from grasses and cereals							
Barley fodder	76.8	2.1	3.3	6.0	11.0	0.8	15
Bermuda grass	66.8	2.3	3.0	8.0	18.9	1.0	2
Bluegrass, Kentucky	68.4	2.8	4.1	8.7	14.8	1.2	32
Brome grass, smooth	67.0	2.9	4.2	9.3	15.1	1.5	35
Buckwheat, Japanese	63.4	3.6	4.6	8.0	19.5	0.9	1
Corn fodder, all analyses	78.1	1.2	1.9	5.2	13.0	0.6	708
Corn fodder, dent, all analyses	76.9	1.2	1.9	5.5	13.9	0.6	260
Corn fodder, dent, in tassel	85.1	1.1	1.6	4.3	7.6	0.3	9

Table I. Average Composition of American Feeding Stuffs—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
Fresh Green Roughage—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Green forage from grasses and cereals—con.							
Corn fodder, dent, in milk	80.1	1.1	1.6	4.9	11.7	0.6	16
Corn fodder, dent, dough to glazing	74.9	1.1	2.1	5.6	15.4	0.9	15
Corn fodder, dent, kernels glazed	73.8	1.2	2.0	6.2	16.2	0.6	26
Corn fodder, dent, kernels ripe	65.2	1.4	2.7	7.4	22.3	1.0	7
Corn fodder, flint, all analyses	79.3	1.0	1.9	4.6	12.6	0.6	94
Corn fodder, sweet, roasting ears or later	79.7	1.2	1.9	4.4	12.2	0.6	55
Corn fodder, sweet, ears removed	78.5	1.3	1.6	5.6	12.6	0.4	3
Crab grass	69.1	4.3	2.7	9.1	13.8	1.0	6
Foxtail or wild barley	64.3	3.5	4.9	11.8	14.1	1.4	9
Johnson grass	70.9	2.0	2.5	9.3	14.4	0.9	14
Kafir fodder	76.4	1.9	2.4	6.6	12.0	0.7	56
Millet, barnyard	78.7	1.6	1.7	6.7	10.7	0.6	43
Millet, common, or Hungarian	72.4	2.1	2.9	8.4	13.3	0.9	19
Millet, pearl, or cat-tail	81.3	1.6	1.8	6.2	8.8	0.3	5
Milo fodder	77.3	1.4	1.8	7.0	12.1	0.4	9
Mixed grasses, immature	70.3	3.0	5.1	6.3	13.8	1.5	6
Mixed grasses, at haying stage	69.2	1.8	3.0	10.6	14.1	1.3	7
Oat fodder	73.9	2.1	3.2	7.8	11.9	1.1	22
Oat fodder, 8 in. high	87.0	1.6	4.9	1.7	4.0	0.8	1
Orchard grass	70.8	2.5	2.9	9.8	12.9	1.1	57
Para grass	72.8	2.4	1.7	9.2	13.4	0.5	2
Red top	60.7	2.7	3.1	12.2	20.2	1.1	16
Rye fodder	78.7	1.7	2.6	7.3	9.0	0.7	38
Sweet sorghum fodder	75.1	1.4	1.5	7.0	14.0	1.0	94
Teosinte	78.7	2.0	1.7	6.7	10.4	0.5	19
Timothy	62.5	2.2	3.1	11.7	19.3	1.2	88
Wheat fodder	72.6	2.7	3.6	7.5	12.8	0.8	15
Green legumes							
Alfalfa, all analyses	74.7	2.4	4.5	7.0	10.4	1.0	143
Alfalfa, before bloom	80.1	2.3	4.7	4.2	7.9	0.8	11
Alfalfa, in bloom	74.1	2.5	4.4	7.8	10.4	0.8	27
Alfalfa, after bloom	70.2	2.2	2.9	12.8	11.3	0.6	6
Beggarweed	72.9	3.2	4.2	7.5	11.7	0.5	3
Clover, alsike	75.7	2.4	4.1	6.5	10.7	0.6	17
Clover, bur	79.2	2.3	5.1	3.9	7.8	1.7	3
Clover, crimson	82.6	1.7	3.0	4.7	7.4	0.6	22
Clover, mammoth red	74.9	2.3	4.0	7.3	11.0	0.5	7
Clover, red	73.8	2.1	4.1	7.3	11.7	1.0	85
Clover and mixed grasses	72.7	1.6	3.0	8.5	13.3	0.9	19
Clover, sweet	75.6	2.1	4.4	7.0	10.2	0.7	18
Clover, white	78.2	2.7	4.6	4.2	9.5	0.8	6
Cowpeas	83.7	2.0	3.0	3.8	7.0	0.5	144
Cowpeas and corn	80.0	1.8	2.1	5.3	10.4	0.4	1
Cowpeas and sorghum	81.3	1.7	1.5	5.5	9.5	0.5	2
Horse bean	82.4	2.0	3.6	4.2	7.3	0.5	5
Peas, field, Canada	83.4	1.6	3.6	4.0	6.9	0.5	33

TABLE I. AVERAGE COMPOSITION OF AMERICAN FEEDING STUFFS—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No of analyses
				Fiber	N-free extract		
FRESH GREEN ROUGHAGE—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Green legumes—con.							
Peas and oats	77.4	2.0	3.2	6.3	10.1	1.0	46
Kudzu vine	69.4	2.2	5.5	8.3	13.6	1.0	1
Lespedeza, or Japan clover	63.4	3.5	6.7	10.7	14.7	1.0	1
Serradella	79.8	3.0	2.9	4.8	8.8	0.7	8
Soybeans	76.4	2.4	4.1	6.3	9.8	1.0	145
Soybeans and corn	76.2	1.7	2.7	5.4	13.2	0.8	9
Soybeans and kafir	82.9	2.1	2.0	6.2	6.2	0.6	1
Velvet bean	82.1	2.0	3.5	5.1	6.6	0.7	1
Vetch, common	79.6	2.1	3.8	5.5	8.5	0.5	14
Vetch, hairy	81.8	2.2	4.2	5.0	6.3	0.5	21
Vetch and oats	73.5	2.3	3.8	7.5	12.0	0.9	15
Vetch and wheat	77.3	1.6	3.3	7.1	10.1	0.6	5
Roots, tubers, etc.							
Artichoke	79.5	1.7	2.0	0.8	15.9	0.1	22
Beet, common	87.0	1.5	1.6	0.9	8.9	0.1	23
Beet, sugar	83.6	1.1	1.6	1.0	12.6	0.1	86
Carrot	88.3	1.2	1.2	1.1	8.0	0.2	18
Cassava	67.4	1.0	1.1	1.4	28.8	0.3	3
Chufa	79.5	0.4	0.7	2.2	10.5	6.6	....
Mangel	90.6	1.0	1.4	0.8	6.1	0.1	38
Parsnip	83.4	1.3	1.7	1.3	11.9	0.4	2
Potato	78.8	1.1	2.2	0.4	17.4	0.1	465
Rutabaga	89.1	1.0	1.2	1.4	7.0	0.3	10
Sweet potato	68.8	1.1	1.8	1.3	26.4	0.6	145
Turnip	90.5	0.9	1.4	1.1	5.9	0.2	20
Miscellaneous green forages							
Apple	81.8	0.4	0.5	1.3	15.6	0.4	9
Apple pomace	76.7	1.0	1.6	4.6	14.5	1.6	17
Cabbage	91.1	0.8	2.2	0.9	4.7	0.3	5
Cactus, cane, entire plant	89.6	1.7	0.9	1.1	6.5	0.2	5
Cactus, prickly pear	83.5	3.4	0.8	2.3	9.7	0.3	94
Kale	88.7	1.9	2.4	1.5	5.0	0.5	12
Kohlrabi	91.0	1.3	2.0	1.3	4.3	0.1	2
Pumpkin, field	91.7	0.9	1.4	1.3	4.2	0.5	4
Rape	83.3	2.2	2.9	2.6	8.4	0.6	37
Saltbush, Australian	76.7	5.4	3.7	4.4	9.4	0.4	7
Sugar beet leaves	88.4	1.8	1.9	1.1	6.5	0.3	5
Sugar beet tops	88.6	2.0	2.6	1.2	5.3	0.3	4
SILAGE							
Alfalfa	75.4	2.9	3.5	8.2	8.6	1.4	2
Apple pomace	79.4	1.0	1.6	4.5	12.2	1.3	14
Barley	75.0	2.6	2.6	9.4	9.4	1.0	2
Clover	72.2	2.5	3.7	9.0	11.5	1.1	14
Corn, well matured	73.7	1.7	2.1	6.3	15.4	0.8	121
Corn, immature	79.0	1.4	1.9	5.8	11.3	0.6	53

TABLE I. AVERAGE COMPOSITION OF AMERICAN FEEDING STUFFS—*continued.*

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat	No. of analyses
				Fiber	N-free extract		
SILAGE—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Corn, from field-cured stover	80.4	1.4	1.4	6.3	9.8	0.7	3
Corn and clover	71.4	2.2	3.3	7.7	14.5	0.9	1
Corn and soybean	75.3	2.0	2.5	6.7	12.5	1.0	15
Cowpea	78.0	2.2	3.2	6.3	9.4	0.9	9
Field pea	72.1	2.6	3.8	7.8	12.5	1.2	8
Japanese cane	77.6	2.0	1.5	8.6	9.7	0.6	1
Kafir	69.2	2.5	1.8	9.9	15.5	1.1	3
Millet	68.4	3.4	2.8	9.7	14.6	1.1	6
Oat	71.7	1.9	2.0	9.8	13.3	1.3	2
Oat and pea	72.5	2.8	3.8	9.6	10.0	1.3	6
Pea-cannery refuse	76.8	1.3	2.8	6.5	11.3	1.3	....
Rye	72.8	2.1	3.0	9.8	11.6	0.7	2
Sorghum, sweet	77.2	1.6	1.5	6.9	11.9	0.9	30
Sorghum and cowpea	67.7	2.2	2.4	8.5	18.2	1.0	8
Soybean	72.9	3.5	3.9	8.1	10.3	1.3	9
Sugar beet leaves	77.0	4.4	2.8	4.7	10.6	0.5	2
Sugar beet pulp	90.0	0.3	1.5	3.1	4.7	0.4	1
Vetch	69.9	2.4	3.5	9.8	13.4	1.0	6
Wet brewers' grains	70.2	1.2	6.4	4.5	15.6	2.1	4

TABLE II. AVERAGE DIGESTIBILITY OF IMPORTANT FEEDING STUFFS

The following digestion coefficients, obtained in experiments with ruminants, for some of the most important American feeds are taken from the extensive table in the unabridged edition of *Feeds and Feeding.* The coefficients marked "H & M" have been compiled by the authors; those marked "L" are from the compilation by Lindsey of the Massachusetts Station; and those marked "M" are from Mentzel and Lengerke's *Landwirtschaftliche Kalender.*

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat	Authority
				Fiber	N-free extract		
CONCENTRATES		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Barley	15	88	78	56	92	78	H & M
Beet pulp, dried	3	75	52	83	83	. . .	H & M
Brewers' grains, dried	5	61	81	49	57	89	H & M
Corn cob	3	54	19	60	52	50	H & M
Corn-and-cob meal	3	79	52	45	88	84	H & M
Corn meal	12	90	74	57	94	93	H & M
Cottonseed meal	15	77	84	37	75	95	H & M
Cowpea meal	2	87	82	64	93	74	H & M
Distillers' grains, largely from corn	17	79	73	95	81	95	L
Emmer	15	..	80	64	89	88	H & M
Flax seed	7	77	91	60	55	86	M
Gluten feed	19	86	85	76	88	85	H & M
Hominy feed	9	83	66	76	90	91	H & M
Kafir, ground	2	..	81	55	92	76	H & M
Linseed meal, old process	3	79	89	57	78	89	H & M
Malt sprouts	5	78	77	87	80	85	H & M
Molasses, cane, or blackstrap	26	78	32	..	90	..	H & M
Oat hulls	1	54	50	60	53	77	H & M
Oats	17	70	78	35	81	87	H & M
Rice polish	4	82	67	26	91	82	H & M
Rye meal	2	87	84	..	92	64	H & M
Skim milk	3	98	94	..	98	98	H & M
Soybeans, ground	15	88	84	81	73	82	M
Wheat, ground	4	87	74	59	93	72	H & M
Wheat bran	20	65	78	31	72	68	H & M
Wheat feed	4	73	77	36	76	87	H & M
Wheat middlings, flour	4	82	88	36	88	86	L
Wheat middlings, stand'd	6	..	77	30	78	88	L
DRIED ROUGHAGE							
Alfalfa hay	109	60	71	43	72	38	H & M
Barley hay	4	59	65	62	63	41	H & M
Bermuda grass hay	9	54	52	52	51	42	H & M
Bluegrass hay, Kentucky	7	56	57	66	61	52	H & M
Brome grass hay	11	63	51	59	64	39	H & M
Clover hay, alsike	15	56	62	48	64	43	H & M
Clover hay, crimson	13	62	69	47	65	44	H & M
Clover hay, red	25	59	59	54	66	57	H & M
Clover and timothy hay	13	55	47	51	60	45	H & M
Corn fodder, dent, mature	30	66	45	63	73	70	L

TABLE II. AVERAGE DIGESTIBILITY OF IMPORTANT FEEDING STUFFS—*continued.*

Feeding stuff	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat	Authority
				Fiber	N-free extract		
DRIED ROUGHAGE—con.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Corn stover	35	57	37	66	59	62	H & M
Cottonseed hulls	13	41	6	47	34	79	L
Cowpea hay	4	59	68	47	68	39	H & M
Johnson grass hay	9	57	44	67	57	46	H & M
Kafir fodder	8	59	46	60	67	60	H & M
Kafir stover	5	56	34	67	60	75	H & M
Millet hay, Hungarian	2	65	60	68	67	64	H & M
Oat hay	22	54	54	52	56	61	H & M
Oat straw	18	54	28	60	51	39	H & M
Orchard grass hay	3	58	60	61	56	55	H & M
Peas and oats hay	7	62	73	58	61	59	H & M
Prairie hay, western	16	..	..	58	53	42	H & M
Red top hay	3	60	62	61	63	53	H & M
Sorghum fodder	20	58	38	61	63	65	H & M
Soybean hay	4	60	73	57	64	44	H & M
Timothy hay	58	55	48	50	62	50	L
Vetch hay, hairy	8	67	79	59	71	67	H & M
FRESH GREEN ROUGHAGE							
Alfalfa	2	61	74	42	72	38	H & M
Beet, sugar	30	..	72	34	97	..	M
Clover, red	2	66	67	53	78	65	H & M
Corn fodder, dent, mature	23	69	54	59	75	75	L
Cowpea	4	68	76	60	81	59	H & M
Mangel	6	84	59	78	94	..	H & M
Oat fodder	5	..	73	55	63	70	H & M
Pea, field, Canada	8	63	81	49	74	54	H & M
Peas and oats	10	70	74	59	68	64	H & M
Potato	30	..	51	..	90	..	M
Rape	4	86	89	87	92	49	H & M
Red top	3	..	61	61	62	50	M
Rutabaga	2	87	80	74	95	84	H & M
Sorghum fodder	6	65	44	55	73	64	L
Soybean	23	64	77	45	75	53	H & M
Timothy	3	63	48	56	66	53	H & M
Vetch, hairy	14	71	83	64	77	72	H & M
SILAGE							
Corn, dent, well matured	27	66	51	65	71	82	L
Corn and soybean	8	69	63	62	77	83	H & M
Kafir, well matured	3	55	..	57	62	50	L
Oat and pea	2	65	75	61	67	75	H & M
Sorghum, well matured	3	57	..	58	64	56	L

Table III. Average Digestible Nutrients and Fertilizing Constituents in American Feeding Stuffs

The data in this table which includes the important American feeding stuffs are taken from the much more extensive table in the unabridged edition of *Feeds and Feeding.* The digestible nutrients have been computed from the data in Appendix Table I and the extensive compilation of digestion coefficients given in the unabridged edition of this book. Where no digestion coefficients are available for any feed, the digestion coefficients for a similar feed have been used and that fact indicated by an asterisk. The total digestible nutrients given in the fifth column is the sum of the digestible crude protein, the digestible carbohydrates, and the digestible fat × 2.25. For convenience in computing rations, the nutritive ratio of each feeding stuff is shown in the sixth column.

The figures for dry matter, digestible crude protein, and total digestible nutrients are printed in black-face type, since these values are the only ones needed in computing rations according to the Modified Wolff-Lehmann Standards given in Appendix Table V.

The fertilizing constituents given are mostly from an exhaustive compilation by the authors of the analyses reported by the State Experiment Stations and the United States Department of Agriculture. A few values have been taken from Mentzel and Lengerke's *Landwirtschaftliche Kalender* for 1914, and other sources.

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Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
CONCENTRATES	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Grains and seeds									
Barley	**90.7**	**9.0**	66.8	1.6	**79.4**	7.8	18.4	8.5	7.4
Broom-corn seed *	**88.2**	**8.3**	62.9	2.6	**77.0**	8.3	16.3	...	...
Buckwheat	**87.9**	**8.1**	49.7	2.5	**63.4**	6.8	17.3	10.0	7.0
Corn, dent	**89.5**	**7.5**	67.8	4.6	**85.7**	10.4	16.2	6.9	4.0
Corn, flint	**87.8**	**7.7**	66.1	4.6	**84.2**	9.9	16.6	6.8	3.9
Corn, soft	**69.4**	**5.5**	53.3	3.5	**66.7**	11.1	11.8	5.4	3.1
Corn, sweet *	**90.7**	**8.5**	64.5	7.3	**89.4**	9.5	18.4	...	...
Corn-and-cob meal	**89.6**	**6.1**	63.7	3.7	**78.1**	11.8	13.8	5.8	6.3
Corn and oat feed, high grade *	**88.6**	**7.3**	60.6	3.4	**75.6**	9.4	15.4	7.5	4.8
Corn and oat feed, low grade *	**90.5**	**6.0**	52.4	3.1	**65.4**	9.9	14.2	5.7	5.1
Cotton seed	**90.6**	**13.3**	29.6	16.5	**80.0**	5.0	31.2	15.0	15.0
Cowpea	**88.4**	**19.4**	54.5	1.1	**76.4**	2.9	37.8	10.1	14.9
Durra grain *	**90.1**	**8.2**	67.9	2.7	**82.2**	9.0	16.2	...	...
Emmer (spelt)	**91.3**	**9.5**	63.2	1.7	**76.5**	7.1	19.0	7.6	5.7
Feterita grain *	**89.2**	**9.3**	66.6	2.5	**81.5**	7.8	18.4	...	...
Flax seed	**90.8**	**20.6**	17.0	29.0	**102.8**	4.0	36.2	15.0	9.5
Horse bean	**87.4**	**22.8**	49.1	0.7	**73.5**	2.2	41.9	12.4	13.4
Kafir grain	**88.2**	**9.0**	65.8	2.3	**80.0**	7.9	17.8	5.7	3.1
Kafir-head chops	**87.5**	**6.1**	56.6	2.0	**66.7**	9.9	15.5	...	...
Kaoliang grain *	**90.1**	**8.5**	67.0	3.3	**82.9**	8.8	16.8	...	...

TABLE III. DIGESTIBLE NUTRIENTS AND FERTILIZING CONSTITUENTS—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
CONCENTRATES—con. *Grains and seeds—con.*	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Millet seed, hog, or broom corn	90.9	8.4	63.7	2.4	77.5	8.2	18.9	7.2	5.2
Milo grain *	89.3	8.7	66.2	2.2	79.9	8.2	17.1	7.8	4.3
Milo-head chops *	89.7	6.3	58.1	1.9	68.7	9.9	16.0	...	...
Oats	90.8	9.7	52.1	3.8	70.4	6.3	19.8	8.1	5.6
Peanut, with hull *	93.5	18.4	15.3	32.6	107.1	4.8	32.6	7.6	6.4
Pea, field	90.8	19.0	55.8	0.6	76.2	3.0	36.6	8.4	10.1
Rice, rough *	90.4	4.7	64.6	1.7	73.1	14.6	12.2	4.9	2.6
Rye	90.6	9.9	68.4	1.2	81.0	7.2	18.9	7.3	5.7
Shallu grain *	90.3	10.1	66.3	2.6	82.2	7.1	20.0	...	...
Sorghum grain *	87.3	7.5	66.2	2.6	79.5	9.6	14.7	8.2	3.3
Soybean	90.1	30.7	22.8	14.4	85.9	1.8	58.4	13.7	24.7
Velvet bean, seed *	88.3	18.1	50.8	5.3	80.8	3.5	33.3	...	...
Velvet bean, seed and pod *	87.7	14.9	51.7	3.8	75.2	4.0	27.4	...	...
Wheat, all analyses	89.8	9.2	67.5	1.5	80.1	7.7	19.8	8.6	5.3
Wheat, spring	89.9	9.2	67.2	1.6	80.0	7.7	20.0	8.6	5.3
Wheat, winter	89.1	8.7	67.8	1.4	79.7	8.2	18.7	8.5	5.2
By-products of factories, etc.									
Beet pulp, dried	91.8	4.6	65.2	0.8	71.6	14.6	14.2	2.4	3.8
Beet pulp, molasses-	92.4	5.9	68.0	0.6	75.3	11.8	15.2	1.5	18.1
Beet pulp, wet *	9.3	0.5	6.5	0.2	7.4	13.8	1.4	0.4	0.7
Brewers' grains, dried	92.5	21.5	30.5	6.1	65.7	2.1	42.4	9.9	0.9
Brewers' grains, wet *	24.1	4.6	8.7	1.5	16.7	2.6	9.1	2.4	0.3
Buckwheat bran, high grade	88.8	10.5	30.4	3.2	48.1	3.6	35.7	16.5	10.0
Buckwheat feed, good grade *	88.2	9.1	30.2	2.9	45.8	4.0	30.9	11.0	7.9
Buckwheat feed, low grade *	88.1	3.7	24.0	2.1	32.4	7.8	21.3	8.4	8.2
Buckwheat hulls *	89.7	0.4	13.9	0.7	15.9	38.8	7.0	5.7	8.6
Buckwheat middlings	88.0	24.6	38.3	6.1	76.6	2.1	45.3	23.4	11.8
Cocoanut meal, low in fat	90.4	18.8	42.0	8.1	79.0	3.2	33.4	12.5	23.7
Corn bran	90.0	5.8	56.9	4.6	73.1	11.6	15.5	6.2	5.4
Corn cob	90.0	0.4	47.3	0.2	48.1	119.2	3.2	0.7	6.6
Cold-pressed cottonseed cake	92.1	21.1	33.2	7.4	70.9	2.4	41.8	...	...
Cottonseed meal, choice	92.5	37.0	21.8	8.6	78.2	1.1	70.6	26.7	18.1
Cottonseed meal, prime	92.2	33.4	24.3	7.9	75.5	1.3	63.7	26.6	18.0

TABLE III. DIGESTIBLE NUTRIENTS AND FERTILIZING CONSTITUENTS—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
CONCENTRATES—con. *By-products of factories, etc.*—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Cottonseed meal, good *	92.1	31.6	25.6	7.8	74.8	1.4	60.2	26.6	18.0
Cottonseed feed	91.7	14.2	30.7	5.7	57.7	3.1	39.2	14.7	14.7
Cottonseed hulls	90.3	0.3	33.3	1.5	37.0	122.3	7.4	3.6	12.8
Distillers' grains, dried, from corn	93.4	22.4	40.4	11.6	88.9	3.0	49.1	6.8	1.7
Distillers' grains, dried, from rye	92.8	13.6	38.0	6.6	66.4	3.9	37.0	8.3	2.4
Distillers' grains, wet *	22.6	3.3	13.3	1.5	20.0	5.1	7.2	1.6	0.4
Flax feed *	90.6	12.0	34.2	12.5	74.3	5.2	26.6	...	...
Flax screenings *	91.4	11.1	35.1	10.4	69.6	5.3	24.6	3.5	12.6
Germ oil meal	91.1	16.5	42.6	10.4	82.5	4.0	36.2	13.2	2.5
Gluten feed	91.3	21.6	51.9	3.2	80.7	2.7	40.6	6.2	2.3
Gluten meal	90.9	30.2	43.9	4.4	84.0	1.8	56.8	5.5	1.2
Hominy feed	89.9	7.0	61.2	7.3	84.6	11.1	17.0	12.4	9.5
Linseed meal, new process	90.4	31.7	37.9	2.8	75.9	1.4	59.0	17.7	13.0
Linseed meal, old process	90.9	30.2	32.6	6.7	77.9	1.6	54.2	17.0	12.7
Malt sprouts	92.4	20.3	47.4	1.3	70.6	2.5	42.2	16.5	18.3
Molasses, beet *	74.7	1.1	59.4	...	60.5	54.0	5.6	0.5	56.3
Molasses, cane, or blackstrap	74.2	1.0	58.2	...	59.2	58.2	5.0	2.4	31.6
Oat bran *	93.6	8.8	36.1	3.9	53.7	5.1	19.5	...	...
Oat dust *	93.4	9.1	34.9	4.3	53.7	4.9	20.2	...	...
Oat feed, low grade	89.8	6.9	37.0	3.2	51.1	6.4	15.4	5.9	6.3
Oat hulls	93.2	2.0	45.2	1.3	50.1	24.1	6.4	2.1	5.8
Oat middlings	92.7	13.0	54.9	6.3	82.1	5.3	26.1	12.7	6.9
Peanut cake, from hulled nuts	89.3	42.8	20.4	7.2	79.4	0.9	76.2	11.6	10.0
Potato flakes, dried *	87.9	3.6	67.2	0.2	71.2	18.8	11.4	...	...
Red dog flour *	88.9	14.8	56.5	3.5	79.2	4.4	26.9	20.0	7.6
Rice bran, high grade	89.9	7.9	38.1	8.8	65.8	7.3	19.4	22.2	12.0
Rice bran, low grade	90.5	7.1	37.7	7.5	61.7	7.7	17.4	22.6	12.2
Rice hulls	90.7	0.3	12.3	0.7	14.2	46.3	5.3	0.9	2.2
Rice polish	90.0	8.0	57.2	7.5	82.1	9.3	19.0	30.8	11.7
Rye bran *	88.6	12.2	56.6	2.8	75.1	5.2	24.5	15.4	9.6
Rye feed (middlings and bran)	88.5	12.2	55.8	2.9	74.5	5.1	24.5	5.6	4.6
Rye middlings *	88.6	12.6	55.5	3.1	75.1	5.0	25.1	5.6	4.9
Soybean meal, fat extracted	88.2	38.1	33.9	5.0	83.2	1.2	66.2	...	...

TABLE III. DIGESTIBLE NUTRIENTS AND FERTILIZING CONSTITUENTS—*continued*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
CONCENTRATES—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
By-products of factories, etc.—con.									
Wheat bran	89.9	12.5	41.6	3.0	60.9	3.9	25.6	29.5	16.2
Wheat feed (middlings and bran)	89.9	12.9	45.1	4.0	67.0	4.2	26.9	21.9	8.8
Wheat flour, patent *	87.7	8.1	69.6	0.9	79.7	8.8	17.4	2.0	1.0
Wheat middlings, flour	89.3	15.7	52.8	4.3	78.2	4.0	28.5	...	...
Wheat middlings, standard (shorts)	89.5	13.4	46.2	4.3	69.3	4.2	27.7	21.1	11.8
Wheat screenings	89.8	9.6	47.3	3.6	65.0	5.8	21.3	7.4	7.6
Animal products									
Buttermilk *	9.4	3.4	4.9	0.1	8.4	1.5	5.8	1.7	1.6
Cow's milk	13.6	3.3	4.9	4.3	17.9	4.4	5.6	1.9	1.7
Dried blood	90.3	69.1	...	0.9	71.1	0.03	131.5	4.9	1.2
Fish meal, high in fat	89.2	37.8	...	11.6	63.9	0.7	77.4	140.0	3.0
Meat-and-bone meal, 30–40% ash *	94.0	37.0	...	11.0	61.8	0.7	63.7	...	...
Meat scrap, high grade *	92.5	55.1	...	11.4	80.7	0.5	...	...	...
Meat scrap, fair grade *	93.3	48.4	...	10.2	71.4	0.5	...	...	...
Poultry bone *	92.7	22.6	...	3.0	29.4	0.3	38.9	...	...
Skim milk, centrifugal	9.9	3.6	5.1	0.2	9.1	1.5	6.1	2.2	1.7
Tankage, over 60% protein *	92.6	58.7	...	12.6	87.0	0.5	101.0	55.8	5.5
Tankage, 55–60% protein *	92.5	54.0	...	12.7	82.6	0.5	93.0	...	...
Tankage, 45–55% protein *	92.5	48.1	...	13.7	78.9	0.6	82.7	101.5	...
Whey *	6.6	0.8	4.7	0.3	6.2	6.8	1.6	1.2	2.6
DRIED ROUGHAGE									
Hay and cured forage from grasses and cereals									
Barley hay, common	92.6	4.6	48.2	0.9	54.8	10.9	11.2	...	...
Bermuda hay	90.3	3.7	37.9	0.8	43.4	10.7	11.4	4.0	20.0
Bluegrass hay, Kentucky	86.8	4.7	43.5	1.5	51.6	10.0	13.3	5.4	21.0
Brome hay	91.5	5.0	44.2	0.9	51.2	9.2	15.8	4.2	21.5
Crab grass	90.5	3.5	40.0	1.0	45.7	12.1	12.8	9.0	30.9
Corn fodder (ears, if any, remaining), very dry, from barn or arid districts	91.0	3.5	51.7	1.5	58.6	15.7	12.5	3.7	9.9

TABLE III. DIGESTIBLE NUTRIENTS AND FERTILIZING CONSTITUENTS—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
DRIED ROUGHAGE *Hay and cured forage from grasses and cereals*—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Corn fodder, medium in water	81.7	3.0	47.3	1.5	53.7	16.9	10.7	3.3	8.9
Corn fodder, high in water	60.7	2.2	35.5	1.0	39 9	17.1	7.7	2.5	6.6
Corn fodder, sweet	87.7	5.9	47.6	1.3	56.4	8.6	14.7	4.0	11.8
Corn stover (ears removed), very dry	90.6	2.2	47.8	1.0	52.2	22.7	9.4	4.5	12.9
Corn stover, medium in water	81.0	2.1	42.4	0.7	46.1	21.0	9.1	4.0	11.5
Corn stover, high in water	59.0	1.4	31.1	0.6	33.9	23.2	6.2	2.9	8.3
Fowl meadow grass hay *	88.9	6.1	43.0	1.4	52.3	7.6	15.7	...	...
Foxtail or wild barley hay *	92.5	4.0	48.4	1.1	54.9	12.7	11.2	...	..
Japanese cane fodder *	93.2	0.5	55.0	1.2	58.2	115.4	2.2	...	...
Johnson grass hay	89.9	2.9	45.0	1.0	50.1	16.3	10.6	4.2	11.3
Kafir fodder, dry	91.0	4.1	45.0	1.7	52.9	11.9	14.2	...	...
Kafir fodder, high in water	71.7	3.0	38.2	1.6	44.8	13.9	10.4	...	...
Kafir stover, dry	83.7	1.7	43.1	1.3	47.7	27.1	8.2	...	...
Millet hay, barnyard	86.5	5.1	40.5	0.8	47.4	8.3	13.3	5.5	25.3
Millet hay, common, or Hungarian	85.7	5.0	46.0	1.8	55.0	10.0	13.3	3.6	21.5
Millet hay, German *	91.3	4.8	49.7	1.7	58.3	11.1	12.8	3.5	14.4
Milo fodder, dry	88.9	1.9	36 3	2.8	44.5	22.4	19.2	...	...
Natal grass hay *	90.2	3.7	37.9	0.8	43.4	10.7	11.8	...	...
Oat hay	88.0	4.5	38.1	1.7	46.4	9.3	13.4	8.0	32.7
Orchard grass hay	88.4	4.7	41.1	1.6	49.4	9.5	12.6	4.0	19.4
Para grass hay	90.2	2.3	38.7	0.4	41.9	17.2	7.4	...	...
Prairie hay, western	93.5	4.0	41.4	1.1	47.9	11.0	12.8	...	...
Red top hay	90.2	4.6	45.9	1.2	53.2	10.6	11.8	4.4	18.8
Sorghum fodder, dry	90.3	2.8	44.8	2.0	52.1	17.6	11.8	...	...
Sorghum fodder, high in water	62.6	1.5	32.9	1.8	38.4	24.6	6.2	...	...
Sudan hay	90.0	2.7	45.4	0.7	49.7	17.4	...	...	...
Teosinte hay *	89.4	5.6	40.2	0.9	47.8	7.5	14.6	7.5	42.6
Timothy hay, all analyses	88.4	3.0	42.8	1.2	48.5	15.2	9.9	3.1	13.6
Timothy hay, cut before bloom	92.8	4.7	42.0	1.6	50.3	9.7	15.7	...	...
Timothy hay, cut at early to full bloom	87.2	3.6	44.7	1.2	51.0	13.2	10.1	...	...

TABLE III. DIGESTIBLE NUTRIENTS AND FERTILIZING CONSTITUENTS—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
DRY ROUGHAGE—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1 :	Lbs.	Lbs.	Lbs.
Hay and cured forage from grasses and cereals—con.									
Timothy hay, cut at late bloom	85.1	2.4	39.0	1.4	44.6	17.6	8.8	...	...
Timothy rowen hay *	84.9	8.2	35.8	2.1	48.7	4.9	23.0	...	...
Wheat hay *	91.9	4.0	48.5	0.8	54.3	12.6	9.9	...	...
Hay from the legumes									
Alfalfa, all analyses	91.4	10.6	39.0	0.9	51.6	3.9	23.8	5.4	22.3
Alfalfa, before bloom *	93.8	15.4	35.5	1.6	54.5	2.5	35.2	...	...
Alfalfa, in bloom	92.5	10.5	38.5	0.7	50.6	3.8	24.0	...	...
Alfalfa, in seed *	89.6	8.5	39.2	1.0	49.9	4.9	19.5	...	...
Alfalfa meal *	91.2	10.2	38.7	0.8	50.7	4.0	22.9	5.4	22.3
Alfalfa leaves *	93.4	15.8	35.1	1.3	53.8	2.4	36.0	...	...
Beggarweed *	90.9	11.6	36.2	0.7	49.4	3.3	24.6	9.4	27.9
Clover, alsike	87.7	7.9	36.9	1.1	47.3	5.0	20.5	7.0	17.4
Clover, bur	93.0	15.6	42.8	0.2	58.8	2.8	30.7	...	...
Clover, crimson, or scarlet	89.4	9.7	36.8	1.0	48.7	4.0	22.6	6.1	22.4
Clover, mammoth red *	81.3	6.4	37.2	1.8	47.6	6.4	17.3	6.3	8.7
Clover, red, all analyses	87.1	7.6	39.3	1.8	50.9	5.7	20.5	3.9	16.3
Clover, red, in bloom	86.1	8.1	38.8	1.8	50.9	5.3	21.0	5.7	15.4
Clover, red, after bloom *	77.9	6.8	34.1	2.6	46.7	5.9	18.6	4.0	11.0
Clover and mixed grasses	89.9	4.7	39.9	1.3	47.5	9.1	15.8	4.1	20.0
Clover and timothy	87.8	4.0	39.7	1.1	46.2	10.6	13.8	4.7	19.0
Clover, sweet, white	91.4	10.9	38.2	0.7	50.7	3.7	23.2	6.6	12.6
Clover, white	91.9	11.8	43.3	1.5	58.5	4.0	25.9	5.2	20.0
Clover rowen	85.2	10.7	33.1	2.2	48.8	3.6	26.4	...	...
Cowpea	90.3	13.1	33.7	1.0	49.0	2.7	30.9	9.6	41.3
Lespedeza, or Japan clover *	88.2	8.6	41.1	1.1	52.2	5.1	19.4	10.3	20.7
Pea, field	88.9	12.2	40.1	1.9	56.6	3.6	24.2	6.7	12.4
Peas and oats	83.4	8.3	37.1	1.5	48.8	4.9	18.2	6.6	16.4
Peanut vine, with nuts	92.2	9.6	39.6	8.3	67.9	6.1	21.3	...	...
Peanut vine, without nuts	78.5	6.6	37.0	3.0	50.4	6.6	14.6	2.2	13.9
Soybean hay	91.4	11.7	39.2	1.2	53.6	3.6	25.6	6.8	23.3
Velvet bean *	92.8	12.0	40.3	1.4	55.5	3.6	26.2	5.5	26.5

TABLE III. DIGESTIBLE NUTRIENTS AND FERTILIZING CONSTITUENTS—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
DRY ROUGHAGE—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Hay from the legumes—con.									
Vetch, common	92.9	11.6	42.8	1.6	58.0	4.0	27.7	7.9	18.6
Vetch, hairy	87.7	15.7	37.1	1.9	57.1	2.6	31.8	10.3	26.2
Vetch and oats	84.3	6.9	37.0	1.4	47.1	5.8	17.0	6.0	12.7
Vetch and wheat	85.0	10.7	41.1	1.3	54.7	4.1	23.2	...	...
Straw and chaff									
Barley straw	85.8	0.9	40.2	0.6	42.5	46.2	5.6	1.8	12.0
Bean straw *	89.5	3.6	42.4	0.7	47.6	12.2	11.7	4.2	13.6
Buckwheat straw *	90.1	4.2	26.3	1.2	33.2	6.9	8.3	1.3	11.3
Cowpea straw *	91.5	3.4	39.1	0.7	44.1	12.0	10.9	...	...
Crimson clover straw *	87.7	3.8	36.5	0.9	42.3	10.1	12.0	...	...
Flax shives	92.8	5.8	25.2	3.0	37.8	5.5	11.5	1.9	10.5
Millet straw *	85.8	1.0	41.7	0.6	44.1	43.1	5.8	1.8	17.3
Oat chaff	91.8	2.2	34.3	1.2	39.2	16.8	9.4	1.3	4.5
Oat straw	88.5	1.0	42.6	0.9	45.6	44.6	5.8	2.1	15.0
Rice straw	92.5	0.9	37.8	0.3	39.4	42.8	6.2	1.4	15.4
Rye straw	92.9	0.7	39.6	0.4	41.2	57.9	4.8	2.8	7.9
Soybean straw	88.1	2.8	38.5	1.0	43.5	14.5	9.0	1.2	8.9
Wheat chaff	85.6	1.1	25.7	0.6	28.2	24.6	6.7	4.0	8.4
Wheat straw	91.6	0.7	35.1	0.5	36.9	51.7	5.0	1.3	7.4
FRESH GREEN ROUGHAGE									
Green forage from grasses and cereals									
Barley fodder	23.2	2.3	11.5	0.4	14.7	5.4	5.3	1.3	6.8
Bermuda grass *	33.2	1.4	17.0	0.5	19.5	12.9	4.8	1.5	7.4
Bluegrass, Kentucky	31.6	2.3	14.8	0.6	18.5	7.0	6.6	1.9	7.1
Brome grass smooth *	33.0	2.9	15.0	0.2	18.3	5.3	6.7	2.0	8.6
Buckwheat, Japanese *	36.6	2.2	17.4	0.5	20.7	8.4	7.4	2.0	9.3
Corn fodder, all analyses *	21.9	1.0	12.8	0.4	14.7	13.7	3.0	1.1	3.7
Corn fodder, dent, all analyses	23.1	1.0	13.7	0.4	15.6	14.6	3.0	1.1	4.5
Corn fodder, dent, in tassel	14.9	1.1	8.2	0.3	10.0	8.1	2.6	....	....
Corn fodder, dent, in milk	19.9	1.0	12.1	0.5	14.2	13.2	2.6	....	....
Corn fodder, dent, dough to glazing *	25.1	1.3	15.4	0.7	18.3	13.1	3.4	....	....
Corn fodder, dent, kernels glazed	26.2	1.1	15.8	0.4	17.8	15.2	3.2	....	....
Corn fodder, dent, kernels ripe	34.8	1.5	21.1	0.8	24.4	15.3	4.3	....	....

TABLE III. DIGESTIBLE NUTRIENTS AND FERTILIZING CONSTITUENTS—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
FRESH GREEN ROUGHAGE—con *Green forage, etc.*—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1 :	Lbs.	Lbs.	Lbs.
Corn fodder, flint, all analyses	20.7	1.0	12.4	0.4	14.3	13.3	3.0	1.0	4.0
Sweet corn fodder, roasting ears or later	20.3	1.2	12.0	0.4	14.1	10.8	3.0	0.9	3.8
Corn fodder, sweet, ears removed * ...	21.5	1.0	13.1	0.3	14.8	13.8	2.6	...	...
Crab grass *	30.9	1.3	14.2	0.5	16.6	11.8	4.3	2.2	10.8
Foxtail, or wild barley *	35.7	2.4	15.9	0.7	19.9	7.3	7.8	...	...
Johnson grass *	29.1	1.2	14.7	0.5	17.0	13.2	4.0	...	...
Kafir fodder	23.6	1.1	12.4	0.4	14.4	12.1	3.8	1.6	5.1
Millet, barnyard	21.3	1.0	12.1	0.4	14.0	13.0	2.7	1.4	6.2
Millet, common, or Hungarian	27.6	1.9	14.8	0.6	18.1	8.5	4.6	1.2	6.9
Millet, pearl, or cattail *	18.7	1.1	10.4	0.2	11.9	9.8	2.9	1.9	10.3
Milo fodder *	22.7	0.8	12.7	0.3	14.2	16.8	2.9	1.7	7.5
Mixed grasses, immature	29.7	3.6	14.5	0.9	20.1	4.6	8.2	2.1	7.9
Mixed grasses, at haying stage	30.8	1.7	15.2	0.6	18.3	9.8	4.8	2.5	6.4
Oat fodder	26.1	2.3	11.8	0.8	15.9	5.9	5.1	1.8	7.7
Oat fodder, 8 in. high *	13.0	3.4	4.1	0.5	8.6	1.5	7.8	...	...
Orchard grass	29.2	1.7	13.0	0.6	16.1	8.5	4.6	2.1	9.5
Para grass *	27.2	0.8	14.0	0.3	15.5	18.4	2.7	...	...
Red top	39.3	1.9	20.0	0.6	23.3	11.3	5.0	2.3	8.4
Rye fodder	21.3	2.1	12.2	0.5	15.4	6.3	4.2	1.5	4.9
Sweet sorghum fodder	24.9	0.7	14.1	0.6	16.2	22.1	2.4	1.1	4.1
Teosinte *	21.3	1.0	11.9	0.3	13.6	12.6	2.7	2.0	9.3
Timothy	37.5	1.5	19.3	0.6	22.2	13.8	5.0	1.8	6.7
Wheat fodder *	27.4	2.8	15.1	0.6	19.3	5.9	5.8	1.9	7.2
Green legumes									
Alfalfa, all analyses .	25.3	3.3	10.4	0.4	14.6	3.4	7.2	1.5	6.7
Alfalfa, before bloom *	19.9	3.5	7.5	0.3	11.7	2.3	7.5	...	...
Alfalfa, in bloom * ..	25.9	3.3	10.8	0.3	14.8	3.5	7.0	...	...
Alfalfa, after bloom *	29.8	2.1	13.5	0.2	16.0	6.6	4.6	1.7	7.9
Beggarweed *	27.1	3.1	11.6	0.2	15.1	3.9	6.7	2.7	5.7
Clover, alsike *	24.3	2.7	11.8	0.4	15.4	4.7	6.6	1.8	9.2
Clover, bur *	20.8	3.4	8.2	1.1	14.1	3.1	8.2	...	...
Clover, crimson	17.4	2.3	8.1	0.4	11.3	3.9	4.8	2.0	4.1
Clover, mammoth red *	25.1	2.7	12.4	0.3	15.8	4.9	6.4	...	...

TABLE III. DIGESTIBLE NUTRIENTS AND FERTILIZING CONSTITUENTS—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
FRESH GREEN ROUGHAGE—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Green legumes—con.									
Clover, red	26.2	2.7	13.0	0.6	17.1	5.3	6.6	1.3	5.6
Clover and mixed grasses *	27.3	2.2	14.1	0.6	17.7	7.0	4.8	...	...
Clover, sweet *	24.4	3.3	10.3	0.3	14.3	3.3	7.0	1.3	5.0
Clover, white *	21.8	3.1	9.6	0.5	13.8	3.5	7.4	1.8	8.1
Cowpeas	16.3	2.3	8.0	0.3	11.0	3.8	4.8	1.4	6.2
Cowpeas and corn *	20.0	1.3	11.4	0.3	13.4	9.3	3.4	...	...
Cowpeas and sorghum *	18.7	0.7	10.0	0.3	11.4	15.3	2.4	...	...
Horse bean *	17.6	2.8	7.4	0.3	10.9	2.9	5.8	1.2	3.7
Peas, field, Canada	16.6	2.9	7.1	0.3	10.7	2.7	5.8	1.1	2.8
Peas and oats	22.6	2.4	10.6	0.6	14.4	5.0	5.1	1.7	6.1
Kudzu vine *	30.6	4.2	13.9	0.5	19.2	3.6	8.8	...	...
Lespedeza or Japan clover *	36.6	4.5	17.1	0.6	23.0	4.1	10.7	...	...
Serradella *	20.2	2.1	8.9	0.5	12.1	4.8	4.6	1.3	4.1
Soybeans	23.6	3.2	10.2	0.5	14.5	3.5	6.6	1.8	5.7
Soybeans and corn *	23.8	1.7	13.6	0.6	16.7	8.8	4.3	1.1	4.0
Soybeans and kafir *	17.1	0.9	7.9	0.4	9.7	9.8	3.2	...	...
Velvet bean *	17.9	2.7	7.2	0.4	10.8	3.0	5.6	1.3	4.5
Vetch, common	20.4	2.7	8.9	0.3	12.3	3.6	6.1	1.6	5.0
Vetch, hairy	18.1	3.5	8.1	0.4	12.5	2.6	6.7	1.4	5.1
Vetch and oats	26.5	2.8	13.3	0.4	17.0	5.1	6.1	1.6	6.3
Vetch and wheat	22.7	2.4	12.2	0.3	15.3	5.4	5.3	...	...
Roots and tubers									
Artichokes *	20.5	1.0	14.6	0.1	15.8	14.8	3.2	1.4	4.9
Beet, common *	13.0	0.9	9.1	0.1	10.2	10.3	2.6	1.0	8.5
Beet, sugar	16.4	1.2	12.6	0.1	14.0	10.7	2.6	0.8	3.2
Carrot	11.7	0.9	8.6	0.2	9.9	10.0	1.9	1.1	2.7
Cassava *	32.6	0.6	26.4	0.2	27.4	44.7	1.8	1.0	4.0
Chufa *	20.5	0.4	10.2	3.3	18.0	44.0	1.1	...	...
Mangel	9.4	0.8	6.4	0.1	7.4	8.2	2.2	0.4	2.2
Parsnip *	16.6	1.3	12.5	0.4	14.7	10.3	2.7	1.3	4.9
Potato	21.2	1.1	15.8	0.1	17.1	14.5	3.5	1.2	5.3
Rutabaga	10.9	1.0	7.7	0.3	9.4	8.4	1.9	1.2	5.0
Sweet potato *	31.2	0.9	24.2	0.3	25.8	27.7	2.9	0.9	5.1
Turnip	9.5	1.0	6.0	0.2	7.4	6.4	2.2	1.3	2.9
Miscellaneous green forages									
Apple *	18.2	0.4	15.6	0.2	16.4	40.0	0.8	0.3	1.6
Apple pomace *	23.3	1.2	15.6	0.8	18.6	14.5	2.6	0.6	1.5

TABLE III. DIGESTIBLE NUTRIENTS AND FERTILIZING CONSTITUENTS—*continued.*

Feeding stuff	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
FRESH GREEN ROUGHAGE—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Miscellaneous green forages—con.									
Cabbage	8.9	1.9	5.6	0.2	7.9	3.2	3.5	0.7	2.9
Cactus, cane, entire plant *	10.4	0.4	5.8	0.1	6.4	15.0	1.4	0.3	2.1
Cactus, prickly pear	16.5	0.4	8.9	0.2	9.7	23.2	1.3	0.7	4.3
Kale	11.3	1.9	4.7	0.3	7.3	2.8	3.8	...	...
Kohlrabi *	9.0	1.7	5.6	0.1	7.5	3.4	3.2	...	...
Pumpkin, field	8.3	1.1	4.5	0.5	6.7	5.1	2.2	0.9	3.2
Rape	16.7	2.6	10.0	0.3	13.3	4.1	4.6	1.1	3.9
Saltbush, Australian *	23.3	2.8	5.9	0.2	9.1	2.2	5.9	3.4	14.1
Sugar beet leaves *	11.6	1.2	6.3	0.1	7.7	5.4	3.0	1.2	5.5
Sugar beet tops *	11.4	1.7	5.4	0.1	7.3	3.3	4.2	1.0	6.4
SILAGE									
Alfalfa *	24.6	1.2	7.8	0.6	10.4	7.7	5.6	...	...
Apple pomace *	20.6	0.9	15.0	0.6	17.3	18.2	2.6	0.8	2.2
Barley *	25.0	2.0	12.0	0.8	15.8	6.9	4.2	...	...
Clover	27.8	1.3	9.5	0.5	11.9	8.2	5.9	...	...
Corn, well matured	26.3	1.1	15.0	0.7	17.7	15.1	3.4	1.6	4.4
Corn, immature	21.0	1.0	11.4	0.4	13.3	12.3	3.0	1.2	3.5
Corn, from field-cured stover *	19.6	0.5	9.9	0.4	11.3	21.6	2.2	...	...
Corn and clover *	28.6	2.1	15.9	0.7	19.6	8.3	5.3	...	...
Corn and soybean	24.7	1.6	13.8	0.8	17.2	9.8	4.0	1.6	4.5
Cowpea	22.0	1.8	10.1	0.6	13.3	6.4	5.1	1.8	3.8
Field pea *	27.9	2.8	13.1	0.9	17.9	5.4	6.1	2.9	2.3
Japanese cane *	22.4	0.6	11.2	0.3	12.5	19.8	2.4	...	...
Kafir	30.8	0.8	15.3	0.6	17.5	20.9	2.9	...	...
Millet *	31.6	1.6	15.3	0.8	18.7	10.7	4.5	...	...
Oat *	28.3	1.5	13.8	0.9	17.3	10.5	3.2	...	...
Oat and pea	27.5	2.8	12.6	1.0	17.6	5.3	6.1	1.7	7.0
Pea-cannery refuse *	23.2	1.6	11.6	0.8	15.0	8.4	4.5	...	...
Rye *	27.2	2.4	16.1	0.5	19.6	7.2	4.8	1.7	6.9
Sorghum	22.8	0.6	11.6	0.5	13.3	21.2	2.4	1.5	1.9
Sorghum and cowpea *	32.3	0.9	16.6	0.6	18.9	20.0	3.8	...	...
Soybean	27.1	2.6	11.0	0.7	15.2	4.8	6.2	1.7	7.1
Sugar beet leaves *	23.0	2.1	10.0	0.4	13.0	5.2	4.5	...	...
Sugar beet pulp *	10.0	0.8	6.5	0.3	8.0	9.0	2.4	...	...
Vetch	30.1	2.0	15.2	0.8	19.0	8.5	5.6	...	...
Wet brewers' grains *	29.8	5.2	11.1	1.9	20.6	3.0	10.2	...	...

TABLE IV. WOLFF-LEHMANN FEEDING STANDARDS FOR FARM-ANIMALS

It has been pointed out in Chapter VII that we now have more accurate data on the nutrient requirements of various classes of animals than were possessed by scientists when the Wolff-Lehmann Feeding Standards were drawn up. As these standards are out-of-date and do not meet present conditions, they should not be used in computing rations for the actual feeding of stock. Instead one of the modern standards should be employed, such as the Morrison, or modified Wolff-Lehmann standards, given in Table V, which are based upon recent experimental work and upon the experiences of practical stock feeders. The Wolff-Lehmann Standards are here given, however, on account of their historical importance.

The standards for milch cows are given for the middle of the lactation period with animals yielding milk of average composition. The standards for growing animals contemplate only a moderate amount of exercise; if much is taken, add 15 per ct.—mostly non-nitrogenous nutrients—to the ration. If no exercise is taken, deduct 15 per ct. from the standard. The standards are for animals of normal size. Those of small breeds will require somewhat more nutrients, amounting in some cases to 0.3 of a pound of nitrogenous and 1.5 pounds of non-nitrogenous digestible nutrients daily for 1,000 pounds of live weight of animals.

Animal	Per day per 1,000 lbs. live weight				
		Digestible nutrients			
	Dry matter	Crude protein	Carbohydrates	Fat	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Lbs.	1:
1. Oxen					
At rest in stall	18	0.7	8.0	0.1	11.8
At light work	22	1.4	10.0	0.3	7.7
At medium work	25	2.0	11.5	0.5	6.5
At heavy work	28	2.8	13.0	0.8	5.3
2. Fattening cattle					
First period	30	2.5	15.0	0.5	6.5
Second period	30	3.0	14.5	0.7	5.4
Third period	26	2.7	15.0	0.7	6.2
3. Milch cows, yielding daily					
11.0 pounds of milk	25	1.6	10.0	0.3	6.7
16.6 pounds of milk	27	2.0	11.0	0.4	6.0
22.0 pounds of milk	29	2.5	13.0	0.5	5.7
27.5 pounds of milk	32	3.3	13.0	0.8	4.5
4. Sheep					
Coarse wool	20	1.2	10.5	0.2	9.1
Fine wool	23	1.5	12.0	0.3	8.5
5. Breeding ewes					
With lambs	25	2.9	15.0	0.5	5.6
6. Fattening sheep					
First period	30	3.0	15.0	0.5	5.4
Second period	28	3.5	14.5	0.6	4.5
7. Horses					
Light work	20	1.5	9.5	0.4	7.0
Medium work	24	2.0	11.0	0.6	6.2
Heavy work	26	2.5	13.3	0.8	6.0

TABLE IV. · WOLFF-LEHMANN FEEDING STANDARDS FOR FARM ANIMALS—*continued.*

Animal		Per day per 1,000 lbs. live weight				
		Dry matter	Digestible nutrients			
			Crude protein	Carbohydrates	Fat	Nutritive ratio
		Lbs.	Lbs.	Lbs.	Lbs.	1:
8. *Brood sows*		22	2.5	15.5	0.4	6.6
9. *Fattening swine*						
First period		36	4.5	25.0	0.7	5.9
Second period		32	4.0	24.0	0.5	6.3
Third period		25	2.7	18.0	0.4	7.0
10. *Growing cattle, dairy breeds*						
Age in months	Av. live wt. per head, lbs.					
2– 3	150	23	4.0	13.0	2.0	4.5
3– 6	300	24	3.0	12.8	1.0	5.1
6–12	500	27	2.0	12.5	0.5	6.8
12–18	700	26	1.8	12.5	0.4	7.5
18–24	900	26	1.5	12.0	0.3	8.5
11. *Growing cattle, beef breeds*						
2– 3	160	23	4.2	13.0	2.0	4.2
3– 6	330	24	3.5	12.8	1.5	4.7
6–12	550	25	2.5	13.2	0.7	6.0
12–18	750	24	2.0	12.5	0.5	6.8
18–24	950	24	1.8	12.0	0.4	7.2
12. *Growing sheep, wool breeds*						
4– 6	60	25	3.4	15.4	0.7	5.0
6– 8	75	25	2.8	13.8	0.6	5.4
8–11	80	23	2.1	11.5	0.5	6.0
11–15	90	22	1.8	11.2	0.4	7.0
15–20	100	22	1.5	10.8	0.3	7.7
13. *Growing sheep, mutton breeds*						
4– 6	60	26	4.4	15.5	0.9	4.0
6– 8	80	26	3.5	15.0	0.7	4.8
8–11	100	24	3.0	14.3	0.5	5.2
11–15	120	23	2.2	12.6	0.5	6.3
15–20	150	22	2.0	12.0	0.4	6.5
14. *Growing swine, breeding stock*						
2– 3	50	44	7.6	28.0	1.0	4.0
3– 5	100	35	4.8	22.5	0.7	5.0
5– 6	120	32	3.7	21.3	0.4	6.0
6– 8	200	28	2.8	18.7	0.3	7.0
8–12	250	25	2.1	15.3	0.2	7.5
15. *Growing, fattening swine*						
2– 3	50	44	7.6	28.0	1.0	4.0
3– 5	100	35	5.0	23.1	0.8	5.0
5– 6	150	33	4.3	22.3	0.6	5.5
6– 8	200	30	3.6	20.5	0.4	6.0
9–12	300	26	3.0	18.3	0.3	6.4

TABLE V. MORRISON FEEDING STANDARDS FOR FARM ANIMALS

Recent investigations of the Experiment Stations of this and other countries have shown that the original Wolff-Lehmann Standards are inaccurate in many instances. Therefore, the following standards have been prepared to provide a more accurate means of computing rations substantially according to the Wolff-Lehmann method. The sources of the recommendations given for the various classes of animals are shown in Chapter VII and the method of computing rations in accordance with these standards is fully explained in Chapters VII and VIII. Modified standards are not presented for growing dairy cattle, growing sheep, and growing pigs (breeding stock), on account of the lack of sufficient data.

In most instances a minimum and a maximum are indicated for dry matter, digestible crude protein, and total digestible nutrients. As has been pointed out in the text, when protein-rich feeds are cheaper than carbonaceous feeds, somewhat more digestible crude protein may be supplied than is stated in the standards. This will narrow the nutritive ratio beyond the limits here indicated. On the other hand, the amount of protein should not fall much below the lower amount indicated. Where a range is indicated in total digestible nutrients, feeding enough concentrates to bring the total digestible nutrients up to the higher figure will generally cause greater production. However, with feeds high in price, it may not be most profitable. (See Pages 112–3.)

Before computing rations for live stock, it is important that the general directions and hints on Pages 86–90 and 103–115 be carefully studied.

	Digestible crude protein	Total digestible nutrients
	Lbs.	Lbs.
1. Dairy cows		
For maintenance of 1,000-lb. cow..........	0.700	7.925
To allowance for maintenance add:		
For each lb. of 2.5 per ct. milk............	0.045–0.053	0.230–0.256
For each lb. of 3.0 per ct. milk............	0.047–0.057	0.257–0.286
For each lb. of 3.5 per ct. milk............	0.049–0.061	0.284–0.316
For each lb. of 4.0 per ct. milk............	0.054–0.065	0.311–0.346
For each lb. of 4.5 per ct. milk............	0.057–0.069	0.338–0.376
For each lb. of 5.0 per ct. milk............	0.060–0.073	0.362–0.402
For each lb. of 5.5 per ct. milk............	0.064–0.077	0.385–0.428
For each lb. of 6.0 per ct. milk............	0.067–0.081	0.409–0.454
For each lb. of 6.5 per ct. milk............	0.072–0.085	0.434–0.482
For each lb. of 7.0 per ct. milk............	0.074–0.089	0.454–0.505

The amount of dry matter to be fed daily per 1,000 lbs. live weight to dairy cows may range from 15.0 lbs. or even less with dry cows to 30.0 lbs. with cows yielding 2.0 lbs. of butter fat per head daily. Cows producing 1.0 lb. of fat per head daily should receive about 21.0 to 25.0 lbs. of dry matter per 1,000 lbs. live weight. The nutritive ratio may readily be found by computation: for example, a 1,200-lb. cow yielding daily 30.0 lbs. of 3.5 per ct. milk will require for maintenance and production 2.31 to 2.67 lbs. digestible crude protein and 18.03 to 18.99 lbs. total digestible nutrients. The nutritive ratio should hence not be wider than 1:6.1 to 1:7.2.

The standards given under Division 2 for growing, fattening steers weighing 1,000 to 1,200 lbs. are for animals being finished on a moderate allowance of concentrates. It will be noted that the amount of total digestible nutrients is considerably lower than the amount indicated under Division 3 for fattening 2-year-old steers on full feed. As has been pointed out in the text, cattle fed a small allowance of concentrates will not make maximum gains. However, under certain conditions this system may return the most profit.

TABLE V. MORRISON FEEDING STANDARDS—*continued.*

Animal	Per day per 1,000 lbs. live weight			Nutritive ratio
	Dry matter	Digestible crude protein	Total digestible nutrients	
	Lbs.	Lbs.	Lbs.	1:
2. *Growing, fattening steers*				
Weight 100 lbs.	14.1	3.2	16.6	4.2
Weight 150 lbs.	20.7	3.3	17.2	4.2
Weight 200 lbs.	24.0	3.4	17.4	4.1
Weight 250 lbs.	25.6	3.0	17.7	4.9
Weight 300 lbs.	26.7	2.7	17.9	5.6
Weight 350 lbs.	25.3	2.4	16.8	6.0
Weight 400 lbs.	24.3	2.2	15.8	6.2
Weight 450 lbs.	24.1	2.1	16.1	6.7
Weight 500 lbs.	23.9	2.1	15.8	6.5
Weight 550 lbs.	23.6	2.0	15.6	6.6
Weight 600 lbs.	23.2	2.0	15.4	6.7
Weight 700 lbs.	22.6	2.0	14.8	6.4
Weight 800 lbs.	21.4	2.0	14.3	6.2
Weight 900 lbs.	20.2	2.0	13.6	5.8
Weight 1,000 lbs.	19.7	1.8	13.5	6.5
Weight 1,100 lbs.	18.1	1.6	12.6	6.9
Weight 1,200 lbs.	17.3	1.5	12.3	7.2
3. *Fattening 2-year-old steers on full feed*				
First 50–60 days	22.0–25.0	2.0–2.3	18.0–20.0	7.0– 7.8
Second 50–60 days	21.0–24.0	1.9–2.3	17.0–19.5	7.0– 7.8
Third 50–60 days	18.0–22.0	1.8–2.1	16.0–18.5	7.0– 7.8
4. *Ox at rest in stall*	13.0–21.0	0.6–0.8	8.4–10.4	10.0–16.0
5. *Wintering beef cows in calf*	14.0–25.0	0.7–0.9	9.0–12.0	10.0–15.0
6. *Horses*				
Idle	13.0–18.0	0.8–1.0	7.0– 9.0	8.0– 9.0
At light work	15.0–20.0	1.0–1.2	9.0–11.0	8.0– 8.5
At medium work	16.0–21.0	1.2–1.5	11.0–13.0	7.8– 8.3
At heavy work	18.0–22.0	1.5–1.8	13.0–15.0	7.6– 8.1
7. *Brood mares suckling foals, but not at work*	15.0–22.0	1.2–1.5	9.0–12.0	6.5– 7.5
8. *Growing colts, over 6 months*	18.0–22.0	1.6–1.8	11.0–13.0	6.0– 7.0
9. *Fattening lambs*				
Weight 50–70 lbs	27.0–30.0	2.7–3.0	19.0–22.0	6.0– 6.7
Weight 70–90 lbs	28.0–31.0	2.5–2.8	20.0–23.0	6.7– 7.2
Weight 90–110 lbs......	27.0–31.0	2.3–2.5	19.0–23.0	7.0– 8.0
10. *Sheep, maintaining, mature*				
Coarse wool	18.0–23.0	1.1–1.3	11.0–13.0	8.0– 9.1
Fine wool	20.0–26.0	1.4–1.6	12.0–14.0	7.5– 8.5
11. *Breeding ewes, with lambs*	23.0–27.0	2.6–2.9	18.0–20.0	5.6– 6.5

TABLE V. MORRISON FEEDING STANDARDS—*continued.*

Animal	Per day per 1,000 lbs. live weight			Nutritive ratio
	Dry matter	Digestible crude protein	Total digestible nutrients	
	Lbs.	Lbs.	Lbs.	1:
12. Fattening pigs				
Weight 30–50 lbs.	46.2–51.0	7.8–8.5	41.0–45.4	4.0– 4.5
Weight 50–100 lbs.	37.0–40.8	5.5–6.0	32.9–36.4	5.0– 5.6
Weight 100–150 lbs.	32.4–35.8	4.4–4.9	28.8–31.9	5.5– 6.2
Weight 150–200 lbs.	29.0–32.0	3.5–3.9	25.8–28.5	6.2– 7.0
Weight 200–250 lbs.	25.5–28.1	3.0–3.4	22.7–25.0	6.5– 7.3
Weight 250–300 lbs.	22.4–24.8	2.6–2.9	20.0–22.0	6.7– 7.5
13. Brood sows, with pigs ..	20.0–24.0	2.4–2.7	18.0–21.0	6.0– 7.0

For the convenience of those wishing to compute rations for poultry, the Wheeler Standards, as given in Jordan's *The Feeding of Animals*, have been converted into the same terms as are used in the Morrison Standards and are here included. Because of the small size of poultry, these standards give the requirements per 100 lbs. live weight rather than per 1,000 lbs. live weight.

	Per day per 100 lbs. live weight		Nutritive ratio
	Digestible crude protein	Total digestible nutrients	
	Lbs.	Lbs.	1:
14. *Wheeler Standards for poultry*			
For maintenance			
Capons of 9 to 12 lbs. wt.	0.30	2.49	7.3
Hens of 5 to 7 lbs. wt.	0.40	2.85	6.1
Hens of 3 to 5 lbs. wt.	0.50	4.12	7.2
For hens in full laying			
Hens of 5 to 8 lbs. wt.	0.65	3.35	4.2
Hens of 3 to 5 lbs. wt.	1.00	5.54	4.5
For chicks			
First 2 weeks	2.0	10.10	4.0
From 2 to 4 weeks of age	2.2	9.52	3.3
From 4 to 6 weeks of age	2.0	8.50	3.2
From 6 to 8 weeks of age	1.6	7.40	3.6
From 8 to 10 weeks of age	1.2	6.28	4.2
From 10 to 12 weeks of age	1.0	5.38	4.4
For ducklings			
First 2 weeks	4.0	18.35	3.6
From 2 to 4 weeks of age	4.1	17.12	3.2
From 4 to 6 weeks of age	2.7	11.28	3.2
From 6 to 8 weeks of age	1.7	8.02	3.7
From 8 to 10 weeks of age	1.4	7.00	4.0
From 10 to 12 weeks of age	0.9	4.55	4.1

TABLE VI. THE FEED-UNIT SYSTEM

Amount of different feeds required to equal one feed unit *

Feed	Feed required to equal 1 unit	
	Average	Range
For dairy cows	Lbs.	Lbs.
Concentrates		
Corn, wheat, rye, barley, hominy feed, dried brewers' grains, wheat middlings, oat shorts, peas, molasses beet pulp, dry matter in roots	1.0	....
Cottonseed meal	0.8	....
Oil meal, dried distillers' grains, gluten feed, soy beans	0.9	....
Wheat bran, oats, dried beet pulp, barley feed, malt sprouts	1.1	....
Alfalfa meal, alfalfa molasses feeds	1.2	....
Hay and Straw		
Alfalfa hay, clover hay	2.0	1.5– 3.0
Mixed hay, oat hay, oat and pea hay, barley and pea hay, red top hay	2.5	2.0– 3.0
Timothy hay, prairie hay, sorghum hay	3.0	2.5– 3.5
Corn stover, stalks or fodder, marsh hay, cut straw	4.0	3.5– 6.0
Soiling crops, silage and other succulent feeds		
Green alfalfa	7.0	6.0– 8.0
Green corn, sorghum, clover, peas and oats, cannery refuse	8.0	7.0–10.0
Alfalfa silage	5.0	....
Corn silage, pea vine silage	6.0	5.0– 7.0
Wet brewers' grains	4.0	....
Potatoes, skim milk, buttermilk	6.0	....
Sugar beets	7.0	....
Carrots	8.0	....
Rutabagas	9.0	8.0–10.0
Field beets, green rape	10.0	....
Sugar beet leaves and tops, whey	12.0	....
Turnips, mangels, fresh beet pulp	12.5	10.0–15.0
The value of pasture is generally placed at 8 to 10 units per day, on the average, varying with kind and condition.		
For pigs		
Indian corn, barley, wheat, oil cakes	1.0	....
Rye, wheat bran	1.4	....
Boiled potatoes	4.0	....
Skim milk	6.0	....
Whey	12.0	....
For horses		
One lb. of Indian corn equals 1 lb. of oats or 1 lb. of dry matter in roots.		

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* The values for pigs and horses are those given in the Danish valuation table and those for dairy cows the values as revised by Woll for American feeding stuffs, given in Wis. Cir. 37.

TABLE VII. ARMSBY'S NET ENERGY VALUES FOR FEEDING STUFFS

The following net energy values for the most important American feeds are taken from Armsby, Pennsylvania Bul. 142. These values were computed by him from the data in Appendix Table III of *Feeds and Feeding*. For a full explanation and discussion of the Armsby net energy values and the feeding standards based thereon see Chapter VII.

Feeding stuffs	Total dry matter	Digestible		Net energy value
		Crude protein	True protein	
	Lbs.	Lbs.	Lbs.	Therms
Grains and seeds				
Barley	90.7	9.0	8.3	89.94
Bean, navy	86.6	18.8	16.4	73.29
Buckwheat	87.9	8.1	7.2	59.73
Corn, dent	89.5	7.5	7.0	89.16
Corn, flint	87.8	7.7	7.2	87.50
Corn-and-cob meal	89.6	6.1	5.7	75.80
Cotton seed	90.6	13.3	11.9	78.33
Cowpea	88.4	19.4	16.9	79.46
Oats	90.8	9.7	8.7	67.56
Pea, field	90.8	19.0	16.6	78.72
Rye	90.6	9.9	9.0	93.71
Soybean	90.1	30.7	27.3	81.29
Wheat	89.8	9.2	8.1	91.82
By-products				
Buttermilk	9.4	3.4	3.4	13.32
Brewers' grains, dried	92.5	21.5	20.2	53.38
Brewers' grains, wet	24.1	4.6	4.4	14.53
Buckwheat bran	88.8	10.5	9.1	30.59
Cottonseed hulls	90.3	0.3	?	9.92
Cottonseed meal, choice	92.5	37.0	35.4	93.46
Cottonseed meal, prime	92.2	33.4	32.0	90.00
Cow's milk	13.6	3.3	3.3	29.01
Distillers' grains, dried, from corn	93.4	22.4	18.3	85.08
Distillers' grains, dried, from rye	92.8	13.6	11.1	56.01
Gluten feed	91.3	21.6	20.1	80.72
Gluten meal	90.9	30.2	28.1	84.15
Hominy feed	89.9	7.0	6.5	81.31
Linseed meal, new process	90.4	31.7	30.9	85.12
Linseed meal, old process	90.9	30.2	28.5	88.91
Malt sprouts	92.4	20.3	12.5	72.72
Molasses, beet	74.7	1.1	0.0	57.10
Molasses, cane, or blackstrap	74.2	1.0	0.0	55.38
Rye bran	88.6	12.2	10.5	79.35
Sugar-beet pulp, dried	91.8	4.6	0.7	75.87
Sugar-beet pulp, wet	9.3	0.5	0.5	8.99
Tankage, over 60 per cent protein	92.6	58.7	55.6	93.04
Wheat bran	89.9	12.5	10.8	53.00
Wheat middlings, flour	89.3	15.7	14.0	75.02
Wheat middlings, standard	89.6	13.4	12.0	59.10
Hay and dry, coarse fodder				
Alfalfa hay, all analyses	91.4	10.6	7.1	34.23
Clover hay, alsike	87.7	7.9	5.3	34.42
Clover hay, red, all analyses	87.1	7.6	4.9	38.68
Corn fodder, medium dry	81.7	3.0	2.3	43.94
Corn stover, medium dry	81.0	2.1	1.6	31.62
Cowpea hay, all analyses	90.3	13.1	9.2	37.59
Millet hay, Hungarian	85.7	5.0	3.9	46.96
Oat hay	88.0	4.5	3.9	32.25
Red top hay	90.2	4.6	3.9	51.22
Soybean hay	91.4	11.7	8.8	44.03
Timothy hay, all analyses	88.4	3.0	2.2	43.02

TABLE VII. ARMSBY'S NET ENERGY VALUES FOR FEEDING STUFFS—*continued.*

Feeding stuffs	Total dry matter	Digestible		Net energy value
		Crude protein	True protein	
Straw	Lbs	Lbs.	Lbs.	Therms
Barley	85.8	0.9	0.6	36.61
Oat	88.5	1.0	0.8	34.81
Rye	92.9	0.7	0.5	17.59
Wheat	91.6	0.7	0.3	7.22
Fresh green roughage				
Alfalfa, in bloom	25.9	3.3	1.8	11.50
Bluegrass, Kentucky, headed out	36.4	2.8	2.2	17.77
Corn fodder, dent, all analyses	23.1	1.0	0.8	14.60
Corn fodder, flint, all analyses	20.7	1.0	0.8	13.53
Oat fodder	26.1	2.3	2.0	14.06
Rape	16.7	2.6	1.7	13.07
Sweet sorghum fodder	24.9	0.7	0.4	15.37
Timothy, in bloom	32.1	1.3	0.8	18.89
Roots				
Beet, common	13.0	0.9	0.1	7.84
Beet, sugar	16.4	1.2	0.4	11.20
Carrot	11.7	0.9	0.5	9.21
Mangel	9.4	0.8	0.1	5.68
Rutabaga	10.9	1.0	0.3	8.46
Turnips	9.5	1.0	0.4	6.16
Silage				
Clover	27.8	1.3	0.8	7.26
Corn, well matured, recent analyses	26.3	1.1	0.6	15.90
Cowpeas	22.0	1.8	1.1	11.05

TABLE VIII. ARMSBY FEEDING STANDARDS FOR FARM ANIMALS

The Armsby Feeding Standards, as recently presented by him in *The Nutrition of Farm Animals*, are as follows. The standards for dairy cows are given on page 100.

Maintenance requirements, per head daily.

Live weight	Cattle		Horses	
	Digestible protein	Net energy	Digestible protein	Net energy
Lbs.	Lbs.	Therms	Lbs.	Therms
150	0.08	1.69	0.08	1.16
250	0.13	2.38	0.13	1.63
500	0.25	3.78	0.25	2.58
750	0.38	4.95	0.38	3.39
1000	0.50	6.00	0.50	4.10
1250	0.63	6.96	0.63	4.76
1500	0.75	7.86	0.75	5.37

Live weight	Sheep		Swine	
	Digestible protein	Net energy	Digestible protein	Net energy
Lbs.	Lbs.	Therms	Lbs.	Therms
20	0.011	0.27	0.010	0.43
40	0.022	0.43	0.019	0.68
60	0.033	0.56	0.029	0.89
80	0.044	0.68	0.038	1.08
100	0.055	0.79	0.048	1.25
120	0.066	0.89	0.058	1.41
140	0.077	0.99	0.067	1.56
160	0.088	1.09	0.077	1.71
180	0.099	1.17	0.086	1.85
200	0.110	1.25	0.096	1.99

TABLE VIII. ARMSBY FEEDING STANDARDS FOR FARM ANIMALS—*continued*

Requirements for growth, including maintenance, per head daily.

(1) Cattle

Age	Beef breeds			Dairy breeds		
	Live weight	Digestible protein	Net energy	Live weight	Digestible protein	Net energy
Months	Lbs.	Lbs.	Therms	Lbs.	Lbs.	Therms
1	125	0.70	3.7	100	0.40	3.1
2	175	0.85	4.2	135	0.45	3.4
3	200	0.90	4.2	165	0.55	3.6
6	350	1.15	5.0	275	0.70	4.1
9	450	1.25	5.7	325	0.75	4.4
12	550	1.40	6.5	400	0.80	5.1
18	750	1.40	8.2	550	0.85	6.4
24	900	1.30	9.3	700	0.85	7.6
30	1000	1.30	9.9	800	0.85	8.2

(2) Sheep

Age	Wool breeds			Mutton breeds		
	Live weight	Digestible protein	Net energy	Live weight	Digestible protein	Net energy
Months	Lbs.	Lbs.	Therms	Lbs.	Lbs.	Therms
3	37	0.13	0.78	40	0.22	0.84
6	65	0.18	0.95	72	0.30	1.03
9	82	0.17	1.06	98	0.28	1.22
12	90	0.15	1.12	115	0.25	1.36
18	100	0.12	1.19	150	0.22	1.64

(3) Swine

Age	Live weight	Digestible protein	Net energy
Months	Lbs.	Lbs.	Therms
1	15	0.10	0.65
2	30	0.20	1.00
3	52	0.30	1.38
6	118	0.40	2.28
9	183	0.50	3.06
12	250	0.55	3.80

Fattening all species of animals with no considerable growth. Daily in addition to the maintenance requirement.

	Per pound of increase in live weight		Digestible protein per 1000 lbs. live weight
	Digestible protein	Net energy	
	Lbs.	Therms	Lbs.
In early stages	0.15	2.50	0.25–0.75
In late stages	0.05	4.00	
Average for entire fattening period	0.10	3.25	

Work horses, daily per 1000 lbs. live weight.

	Digestible protein	Net energy
	Lbs.	Therms
Full work—8 hours per day	2.0	18.2
Half work—4 hours per day	1.4	11.1
One-fourth work—2 hours per day	1.0	7.6

TABLE IX. WEIGHT OF VARIOUS CONCENTRATES

In computing rations for farm animals it is desirable to know the weight per quart, or the bulk, of the different concentrates. The following table, compiled from *Massachusetts Bulletin 136* by Smith and Perkins, *Louisiana Bulletin 114* by Halligan, and *Indiana Bulletin 141* by Jones, Haworth, Cutler, and Summers is therefore presented.

Feeding stuffs	One quart weighs	One pound measures	Feeding stuff	One quart weighs	One pound measures
	Lbs.	Qts.		Lbs.	Qts.
Whole corn	1.7	0.6	Millet, foxtail	1.6	0.6
Corn meal	1.5	0.7	Rice polish	1.2	0.8
Corn-and-cob meal	1.4	0.7	Rice bran	0.8	1.3
Hominy feed	1.1	0.9	Buckwheat	1.4	0.7
Gluten feed	1.3	0.8	Buckwheat flour	1.6	0.6
Gluten meal	1.7	0.6			
Germ oil meal	1.4	0.7	Buckwheat middlings	0.9	1.1
Corn bran	0.5	2.0	Buckwheat bran	0.6	1.7
Wheat	1.9	0.5	Buckwheat hulls	0.5	2.0
Wheat, ground	1.7	0.6	Cotton seed	0.8	1.3
Flour wheat middlings	1.2	0.8	Cottonseed meal	1.5	0.7
			Cottonseed hulls	0.3	3.3
Standard wheat middlings	0.8	1.3	Flaxseed	1.6	0.6
Wheat bran	0.5	2.0			
			Linseed meal, old process	1.1	0.9
Wheat feed (shorts and bran)	0.6	1.7			
Wheat screenings	1.0	1.0	Linseed meal, new process	0.9	1.1
Rye	1.7	0.6	Flax feed	0.8	1.3
Rye meal	1.5	0.7	Flax screenings	1.1	0.9
Rye middlings	1.6	0.6	Beans, navy	1.7	0.6
Rye bran	0.8	1.3	Cowpeas	1.7	0.6
Rye feed (shorts and bran)	1.3	0.8	Peas, field	2.1	0.5
Oats	1.0	1.0	Soybeans	1.8	0.6
Oatmeal	1.7	0.6	Cocoanut meal	1.5	0.7
Oats, ground	0.7	1.4	Cocoanut cake	1.3	0.8
Oat feed	0.8	1.3	Sunflower seed	1.5	0.7
Oat middlings	1.5	0.7	Beet pulp, dried	0.6	1.7
Oat hulls	0.4	2.5			
Barley	1.5	0.7	Distillers' grains, dried	0.6	1.7
Barley meal	1.1	0.9			
Malt sprouts	0.6	1.7	Molasses, cane, or blackstrap	3.0	0.3
			Molasses feed	0.8	1.3
Brewers' grains, dried	0.6	1.7	Alfalfa meal	0.6	1.7

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